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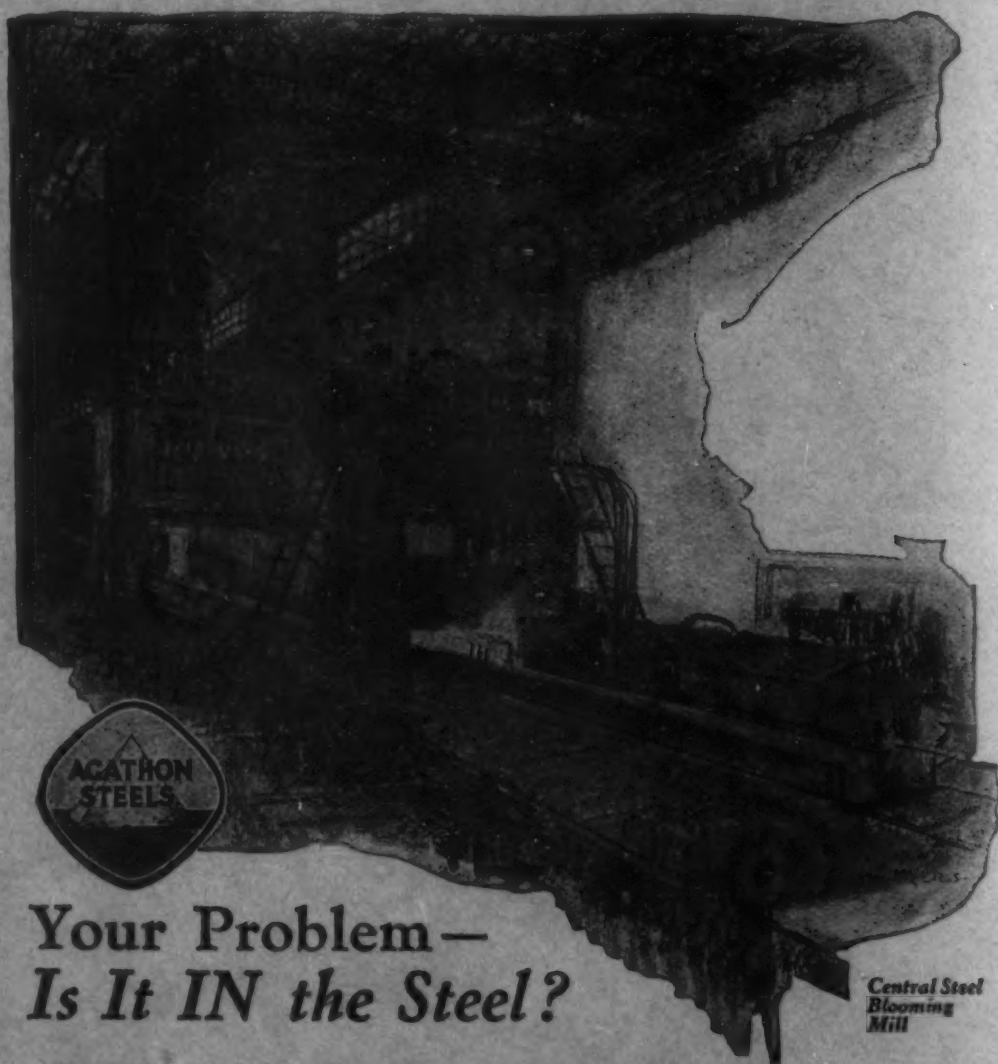
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## Your Problem— *Is It IN the Steel?*

**P**ERHAPS your requirement is for a steel a little harder, tougher, stronger, more dense, more easily susceptible to heat treatment. Then Agathon Alloy Steels will serve your purpose best.

Let our research laboratories and metallurgical engineers assist in working out your steel problems by experiment. We have had years of experience in adapting our steels to hundreds of lines of manufacture. Write us regard-

ing the part or product you wish to improve with alloy steel.

Production in all standard alloy steels and special analysis alloy steels—Nickel, Chrome-Nickel, Manganese, Molybdenum, Chrome-Molybdenum, Nickel-Molybdenum, Vanadium, Chrome-Vanadium, Chromium, etc. Furnished in Blooms, Bars, Slabs, Billets, Rods, Strips, etc.

We also produce High-Finish Sheets and Hot-Rolled Strips in straight carbon steels.

## THE CENTRAL STEEL COMPANY

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Peoples Gas Bldg.  
Chicago

University Block  
Syracuse

Widener Bldg.  
Philadelphia



# TRANSACTIONS

of the  
*American Society for Steel Treating*

Vol. II

Cleveland, August 1922

No. 11

## THE BUSINESS SITUATION

THE apparent recovery of business in the United States has characterized the first half of 1922. Last year was not only a year of depression but was one of readjustment. The prosperity which followed the World War had come to an abrupt ending. Industrial and commercial concerns that had made large and easy profits during the war years, suddenly found themselves with large stocks of goods on hand which had diminished very decidedly in market value, and which could not be sold even at the lower prices to which they had been marked.

Under these conditions such concerns were slow in meeting their debts. Interest rates were climbing and with profits shrinking and in many cases disappearing, thousands of previously prosperous institutions were forced into insolvency. During the year 1921, commerce and industry slowed down to a point of business stagnation, financial loss and unemployment that have very seldom been equalled in similar periods in the country's history.

Periods of readjustment in the human relations of large numbers of people are slow and painful. There are few kinds of readjustment excepting those resulting from war, pestilence and famine which are as trying as that resulting from the downward readjustment in prices. Business slows down, industry diminishes and general hard times result.

During the first six months of this year we have had a general period of recovery. Interest rates have been falling and many companies that were in hard straights are beginning to see the light of day. Money is more readily obtainable and at easier rates, which augurs well for industrial and commercial expansion. Probably due to the slowed down activity in building during the period of war, a building boom is now in progress in the country and is of proportions which have never been equalled in our history. Continued progress in this direction will soon fill the building and housing shortage which accumulated during the war days and those following. It is reported that the banking situation of the country has been constantly improving until it now stands in a very good condition.

The bond markets have been very active and has provided millions of dollars in new capital for business in general. Prices to a large extent have stopped their downward trend and are now near enough in line with each other to permit a profit instead of a loss as has been the case in most industries.

Liberty bonds have been climbing in value until they now stand at par or better. The demand for rail and industrial stocks has risen

very decidedly and has placed considerable new capital in the hands of these interests to work with. In addition to the unprecedented building activity there have been two other cases of particularly significant industrial recovery. The first of these is the iron and steel industry, in which production has had an unprecedented period of improvement. The second is the automobile industry which has had a very decided business boom.

In summing up conditions it can be truly said that the first half of the year 1922 has been one of exceptionally vigorous recovery after the previous year of readjustment. There is every reason to believe that this condition will continue in spite of the fact that the rail and coal strikes are distressing the country at present. It is unlikely that these present handicaps will materially hinder the steady business improvement which the United States is now enjoying.

### ALLEN-A-DALE OR SOCRATES

Sir Walter Scott masterfully portrayed in his Waverly novels the delectable and interesting characterists of the ancient Minstrels. No one was more forcibly presented than Allen-a-Dale, who journeyed from place to place and group to group singing his "merrie" lays to the great enjoyment if not of profit, of his many auditors. Entertainment was his fort and merri-ment reigned supreme wherever he pleased to wander and present himself.

Quite in contrast with the Scott character was the wise and gifted Socrates whose inspiring philosophy and interesting teachings made him a welcome guest and attracted to his sphere of influence those thirsting for a knowledge of the best things of life. Knowledge and inspiration, not levity, were his forte and consequently we recall with a less degree of effort, the teachings of Socrates than the lays of Allen-a-Dale.

Sales representatives have within their power the possibility of exercising characteristics and influences similar to the two types mentioned. There are many salesmen when making a call who feel it incumbent that they should divert themselves of sundry and so-called "stories" in an earnest endeavor to reach a common ground and understanding. Such representatives, while they may flatter and congratulate themselves upon the impression they believe they may have made, should wait until their next visit when the great possibility exists that they will warm the "mourner's bench" for an ungracious period or get the "too busy" signal.

If we admit there are too many salesmen of the Allen-a-Dale variety so must we readily consent to the proposition that there are too few of the "Socraterian" types. The salesman intelligently dispensing valuable information, such as the work of the research department of his organization has developed or his own knowledge and experience gathering facilities have accumulated, will always receive a cordial reception and unconsciously lay the foundations of confidence between user and producer, upon which, in the final analysis, the greatest portion of business is conducted.

Selling is an art as well as an honorable profession, and the success of some salesmen as contrasted to others, might well be the subject of analytical thought to determine if those characteristics and traits contributing to their advancement emulate the characteristics and traits of Allen-a-Dale or Socrates.

### IT PAYS

No matter how altruistic our inclinations may be, stern necessity usually inquires, "Does it pay?" It is fortunate this constant check to our activities arises, otherwise we might disperse our earnings with a reckless abandon that would not augur well for the good of society in general. Experience has shown that there are some things that pay, such as savings accounts, careful investments, good health, efficient production and advertising. That it pays to advertise is a most generally accepted truth that has been decisively demonstrated. It is interesting to note that advertising pays dividends because whether it is direct mail, news, trade or society publication or exhibiting at expositions and conventions, it is the only means offered to the manufacturer to acquaint the possible user with his product.

While the man with a better mouse trap might have a path worn through the woods to his door, at the time of Emerson, it is doubtful if a light thus concealed under a basket would create any competition in this enlightened day. The recipient of a publication reads the advertisements with as great care as the short stories or technical articles. He has been educated to read the advertising section and no advertisement with a real message escapes his notice. The consumer realizes what a great obligation he owes to advertising mediums. It is to these he turns when in need because he realizes that a manufacturer who believes in his product so strongly that he is willing to tell the world about it undoubtedly has a product it would pay him to investigate. Advertising is not a one-sided dividend producer—it pays both the producer and the consumer.

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### RESEARCH AND ITS REWARD

Beyond all question of doubt the results obtained as the result of well directed research are most gratifying to the scientific world. The results observed and the data obtained form the basis of extended researches as well as forming a new or perhaps firmer foundation upon which the commercial world as well as the scientific world may base new theories or production. In this issue of the TRANSACTIONS a very interesting and commendable piece of research has been recorded. The author, S. C. Spalding, has made a real contribution to our knowledge of carburizing. It is regrettable that space did not permit of the exhibition of all of the photomicrographs which were obtained in the work, but those which are included show perhaps the penetration contrasts better than would have been the case if all of the photomicrographs had been reproduced. Mr. Spalding's metallurgical experience has been long and varied and his ability in conducting researches has been well demonstrated.

In this work the author has accomplished two important things. He has established additional accurate data to the art of carburizing steels and he has proven his ability as an experimenter. The reward therefore which accompanies well directed effort regardless of its nature is perhaps many fold. Chief among these rewards are the benefits which the world at large will derive from such effort and the gratification which the author will have in knowing he has rendered a real service to mankind.

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## HOTEL RESERVATIONS FOR DETROIT CONVENTION

Statler Hotel, Convention  
Headquarters

**I**N ORDER that all of our members and guests who will attend the fourth annual convention of the Society, may not be disappointed or inconvenienced in obtaining hotel accommodations, the following list of hotels, their rates and the number of guests they can accommodate are again being printed. Hotels in Detroit already are reporting heavy registration for the week of October 2nd. Thus it is important that members and guests who are planning to be present should write immediately to the various hotels in order to secure their reservations. The Statler Hotel will be the official headquarters but it is probable that it will not be possible for this hotel to accommodate all of our guests unless reservations are made immediately. All persons in attendance at the Detroit convention will

make their own hotel reservation direct with the managers and it is advisable that the members take the following precaution: When making reservations, state that you are attending the International Steel Exposition and Convention of the American Society for Steel Treating, give the date of arrival, kind of room desired and the price you wish to pay. Request the hotel manager to answer your letter repeating the reservation, then take the letter with you to Detroit and present it when you register. This precaution taken now may avoid annoying difficulty during the rush of the Convention. It is recommended that reservations be made immediately.

The list of hotels follow:

**Charlevoix Hotel**

Rate With Bath	Two-Room Suites.....	\$7.00
Single \$3.00, \$3.50, \$4.00	Three-Room Suites .....	\$8.25
Double \$5.00, \$6.00	Four-Room Suites .....	\$9.00

Number of persons with notice—100

**Hotel Wolverine**

Rate With Bath
Single \$2.50, \$3.00, \$3.50, \$4.00, \$4.50, \$5.00, \$6.00
Double \$4.50, \$5.00, \$5.50, \$6.00, \$6.50, \$7.00, \$8.00

Will accommodate 300

**Hotel Norton**

Rate Without Bath	Rate With Bath
Single \$2.00 to \$2.25	Single \$2.50 to \$3.00
Double \$4.00	Double \$4.50 to \$5.50

Will accommodate 100

**Lincoln Hotel**

Rate Without Bath	Rate With Bath
Single \$1.25, \$1.50, \$1.75, \$2.00	Single 6 showers and tubs on each floor
Double \$2.50, \$3.00 (2 men)	Double no private baths

Will accommodate 75

Remarks: Large lobby. Good cafeteria.

**Hotel Fort Shelby**

Rate Without Bath  
Single \$2.00  
Double \$3.00

Rate With Bath  
Single \$3.00, \$3.50, \$4.00, \$5.00  
Double \$5.00, \$6.00, \$7.00

Will accommodate 50 to 100

**Cadillac Hotel**

Rate Without Bath  
Single 2.00, \$2.50  
Double \$3.00, \$3.50, \$4.00

Rate With Bath  
Single \$2.50, \$3.00, \$3.50, \$4.00  
Double \$4.00, \$5.00, \$6.00, \$7.00

Will accommodate 500

**Hotel Normandie**

Rate Without Bath  
Single \$1.50 to \$2.00  
Double \$2.50 to \$3.00

Rate With Bath  
Single \$2.50 to \$3.00  
Double \$3.50 to \$4.00

Will accommodate 100

**Madison-Lenox**

Rate Without Bath  
Single \$2.00  
Double \$3.00

Rate With Bath  
Single \$2.50, \$3.00  
Double \$3.50, \$4.00

Will accommodate 100 or more

**Library Park Hotel**

Rate Without Bath  
Single \$1.25 to \$2.00  
Double \$2.00 to \$3.00

Rate With Bath  
Single \$3.00  
Double \$4.00

Will accommodate 50

**Hotel Stevenson**

Rate With Bath  
Single \$2.50  
Double \$3.50

Will accommodate 50

**Hotel Statler**

Rate With Shower  
Single \$3.00 to \$3.50  
Double \$5.00 to \$5.50

Rate With Bath  
Single \$4.00 to \$ 8.00  
Double \$6.00 to \$10.00

Will accommodate—400 rooms to take care of 600 to 800 people

**Hotel Tuller**

Rate With Bath  
Single \$2.50  
Double \$4.50

Will accommodate 300

**Hotel Griswold**

Rate Without Bath  
Single \$2.00  
Double \$3.00

Rate With Bath  
Single \$2.50, \$3.00, \$3.50  
Double \$4.00, \$5.00, \$6.00

Will accommodate 125

**Hotel Addison**

Rate Without Bath  
Single \$1.50  
Double \$3.00

Rate With Bath  
Single \$2.50  
Double \$4.00

Will accommodate 250

## EXHIBITORS AT THE INTERNATIONAL STEEL EXPOSITION

THE exhibition this year will be the most interesting and important the Society has ever held. There will be more exhibits in operation than ever before. Over 75 firms, as listed below, producing the highest class of products will be there to meet you and greet you, and not only to explain their products but to answer any questions you may have, and help you solve any difficulties in which you may be entangled.

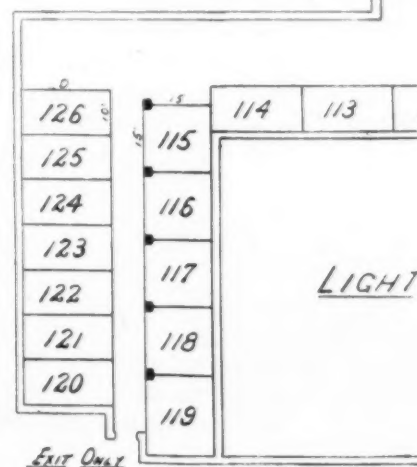
A glance at the list of firms below will show that they represent the leaders, and they are anxious that you should examine their products.

## FLOOR PLAN AND LIST OF EXHIBITORS

1	2	3	4	5	6	7	8	9	10	11	12
33	34	35	36	37	38	39	40	41	42	43	
51	52	53	54	55	56	57	58	59	60		

## LIST OF EXHIBITORS

Alcorn, Blockhouse & Co.  
Allied Metal Products Corp.  
American Drop Forging Institute  
American Car & Foundry Co.  
American Cyanimid Company  
American Kreuger & Toll Corp.  
American Twist Drill Co.  
Ajax Manufacturing Company  
Armstrong-Blum Mfg. Company  
Armstrong Cork & Insulation Co.  
Bausch & Lomb Optical Company  
Bellevue Industrial Furnace Co.  
Blaich Company, The Alfred O.  
Bristol Company  
Brown Instrument Company  
Bureau of Standards  
Calorizing Company of Pittsburgh  
Carborundum Company  
Case Hardening Service Company  
Celite Products Company  
Central Steel Company  
Climax Molybdenum Company  
Colonial Steel Company  
Crucible Steel Company of America  
Dearborn Chemical Company



Driver-Harris Company  
Electric Alloy Steel Company  
Electro Alloys Company  
Electric Furnace Co.  
Engelhard, Inc., Chas.  
Firth-Sterling Steel Company  
Finkl & Sons, A.  
Ford Company, The J. B.  
Forging & Heat Treating  
Ganschow Company, Wm.  
General Alloys Company  
General Electric Company  
Hagan Company, The Geo. J.  
Halcomb Steel Company

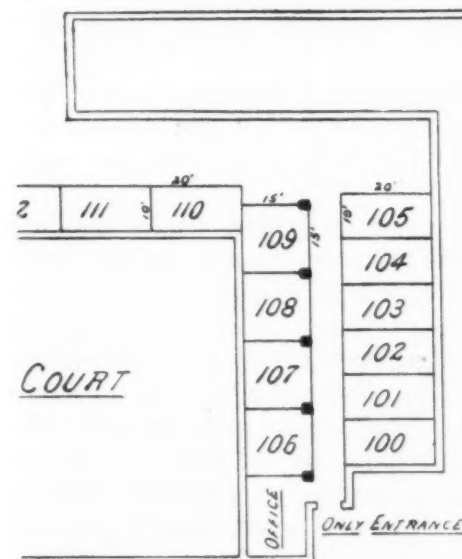
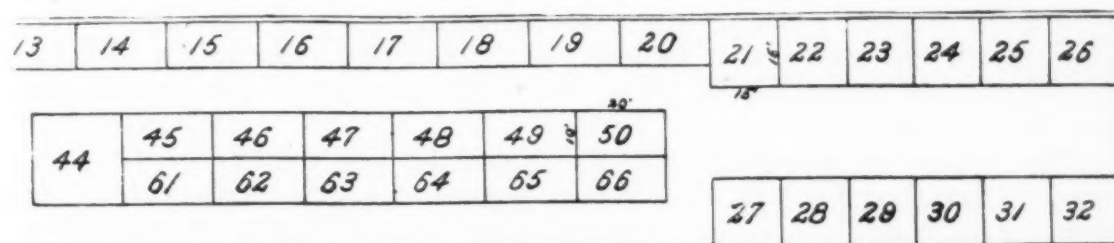


There is nothing that could be of greater value to you than to come to the Convention and Exhibition to examine at first hand the very latest in new equipment and products which should be used.

The list of exhibitors given below is not complete due to the fact that it was necessary to close the forms preparatory to going to press. The program distributed at the Convention will contain complete information.

Following is the exhibition hall floor plan and a partial list of exhibitors who will be present.

### INTERNATIONAL STEEL EXPOSITION DETROIT, MICHIGAN



Haynes-Stellite Company  
Heppenstall Forge & Knife Co.  
Holcroft & Company  
Hoskins Manufacturing Company  
Houghton & Company, The E. F.  
Hoover Steel Ball Co.  
International Nickel Company  
Interstate Iron & Steel Company  
Iron Age  
Keller Mechanical Engraving Co.  
Keystone Refractories  
Kleist & Co., Chas.  
Leeds & Northrup Company  
Leitz, Inc., E.  
Machinery

McPhee Cement Company  
Midvale Steel & Ordnance Company  
Mid-West Steel & Supply Co.  
Motch & Merryweather Machinery Co.  
National Machinery Company  
Obermayer Company, The S.  
Olsen Testing Machine Co., Tinius  
Pangborn Corporation  
Park Chemical Company  
Penn Seaboard Steel Corporation  
Quigley Furnace Specialties Co.  
Rockwell Company, The W. S.  
Rodman Chemical Company  
Shore Instrument & Mfg. Co.  
Simonds Steel Company  
Spencer Turbine Company  
Standard Alloys Company  
Standard Fuel & Engineering Co.  
Surface Combustion Company  
Taylor Instrument Company  
Taylor Company, The N. & G.  
United Alloy Steel Company  
Vanadium-Alloys Steel Company  
Vanadium Corporation of America  
Westinghouse Electric & Mfg. Co.  
Wilson-Maeulen Company  
Witherow Steel Company

## A COMPARISON OF THE RATE OF PENETRATION OF CARBON INTO VARIOUS COMMERCIAL STEELS IN USE FOR CASE CARBURIZING

By S. C. Spalding

THE changing of iron or low carbon soft steel into high carbon steel possessing extreme hardness after quenching, by a process which does not require the fusion of the metal, is an art that has been in practice for many hundreds of years. In the olden days, the individual who accidentally or otherwise discovered a method of case hardening, guarded his secret jealously, therefore the art was practiced long before any evidence of it was set down in writing. A certain smith would be known to have some wonderful method of producing superior tools from ordinary iron but his work would be shrouded in great mystery, only to be performed in certain favorable phases of the moon, and such occult foolery. Such methods used by the first man for concealment were passed on as an essential part of the process thus obscuring its true principles.

The earliest written evidence of the use of this cementation or carburizing process is found in the writings of Vannuccio Biringuccio, published in 1540 under the title of "Pirotechnia" and in the treatise "De re Metallica" by George Agricola, published in 1556. Both of the above authorities describe a method of heating soft iron billets in a bath of molten cast iron from which they absorbed carbon and became capable of taking on a hard surface. The early uses of the carburizing process seem to have been for the production of a superficial hardening on finished articles of soft iron similar to our modern case hardening.

Beginning in the seventeenth century the process began to be applied to carburizing completely whole bars or billets of iron transforming them into steel, which were subsequently forged into finished shapes. At this time this was the only method for the production of steel, and its discovery led to a wide increase in the use of the cementation process in which case hardening became only a minor issue. The discovery of the crucible process in 1740 by Huntsman, in which steel produced from iron by cementation was used as the raw material, gave greater impetus to cementation or carburizing. These conditions continued until the invention of puddled steel in 1830, followed shortly by the Bessemer process and the open-hearth process which practically did away with the manufacture of steel by total cementation and the carburizing process reverted to its original purpose, the production of surface hardness on finished soft steel parts. In this field carburizing still finds extensive use. At the present time many special steels are made which are adapted to the production of finished parts with a hard wearing surface encasing a soft tough core. It is with this phase, the modern case carburizing process, that the data in this paper is concerned.

### Purpose of Investigation

Many investigators have worked on the problem of the effect of carburizing agents on steels, but the problem is always rendered more complex by the introduction of new steels suited or said to be suited to the process, until the present day users have a large number of steels from which they must select the one best suited to their needs with no exact data on which to base

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A paper presented at the Indianapolis Convention of the Society. The author, S. C. Spalding is metallurgist, Halcomb Steel Co., Syracuse, N. Y.

their selection. The most complete and exhaustive treatise on the subject at present available, is Dr. Giolitti's work "The Cementation of Iron and Steel." In this work there is collected, summarized and discussed all of the work which had been done by other investigators up to the time of its publication, 1912. Lothrop, in his paper entitled "Case Carbonizing," published in the *Transactions* of the American Society of Mechanical Engineers, 1912 gives much valuable data on plain carbon, nickel and chromium vanadium steels. A number of articles have appeared in the *TRANSACTIONS* of the American Society for Steel Treating, but have dealt mostly with furnaces, methods, costs, etc., rather than comparing the rates of penetration of different steels. The apparent lack of comparative information on the rate of penetration under identical conditions of different commercial carburizing steels, led to the securing of the data which is here published, with the hope that they may make a valuable addition to the information available to the user of case carburizing steels.

The steels investigated comprise a plain carbon cold rolled steel, a plain carbon hot rolled steel, a chromium silico-manganese steel, a chromium-vanadium steel, a  $3\frac{1}{2}$  per cent nickel steel, a 5 per cent nickel steel, two types of chromium nickel steel and a chromium molybdenum steel. The material from which the specimens were made was in the form of 1 inch round bars. The test pieces were cylinders  $\frac{3}{4}$  of an inch round by 2 inches long. One piece from each bar was packed in a cylindrical pot as shown in Fig. 1.

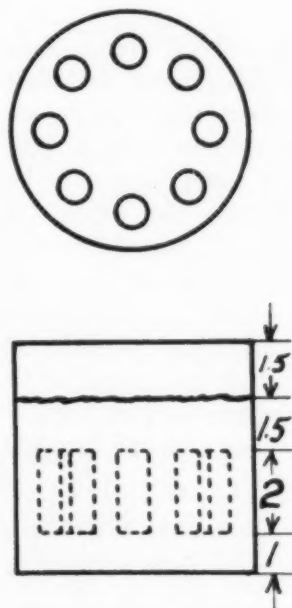


Fig. 1 Arrangement of test pieces in carburizing box for carburizing penetration investigation.

The carburizing agent was a standard commercial compound. The boxes were made of sections cut off pipe with a bottom welded in one end. A circular plate fitting inside the top was used as a cover, this cover being luted on with fire clay. Sixteen boxes were loaded into a large oil-fired heating furnace having a hearth 6 feet wide and 20 feet long heated by five oil burners and equipped with pyrometers so that all parts of the furnace could be kept at a uniform temperature. The boxes were brought up to temperature and the period of carburizing computed from that time. After five



hours at temperature, two boxes were pulled out. At the next time interval of five hours two more were pulled out, etc. This gave duplicate specimens for each period of time, each from a different box. When the boxes had cooled down the cylinders were taken out, the end cut off, then slit in two longitudinally as shown in Fig. 2. The depth of case was read with the aid of the microscope, measuring in from the end surface until a point was reached where the carbon had fallen to approximately 50 per cent.

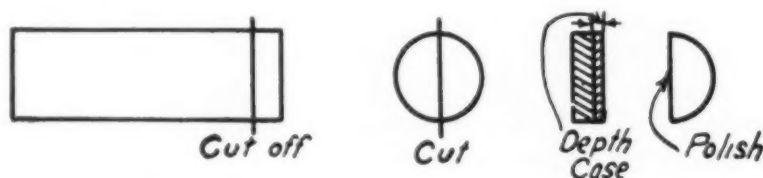


Fig. 2 Method of cutting specimens for microscopic examination.

Two runs were made, one at 1600 degrees Fahr. and one at 1700 degrees Fahr., with time periods at 5, 10, 15, 20, 25, 30, 40 and 50 hours. To check up some irregularities an additional run was made at 1700 degrees Fahr., with time periods of 20, 22½, 25, 27½, 30, 40, 50 and 55 hours. In each of the 1700 degree Fahr. runs a large oil-fired furnace was used and all the boxes were loaded in at the start and pulled out as their time came. In the 1600 degree Fahr. run it was not possible to have the use of this furnace and a smaller oil-fired furnace was used in which only four boxes could be loaded at a time. The 5 and 10 hour runs were made together, then the 15 and 20, etc.

The chromium molybdenum data were obtained in a separate run by packing two specimens of the chromium molybdenum steel with a specimen of the chromium vanadium steel in the same box, using the same large furnace, the same method of pulling the boxes, etc. The chromium vanadium steel, on which we already had data, gave a base with which to compare the chromium molybdenum steel with the other steels. The chemical composition of the steels used in this investigation are shown in Table I.

A complete microscopic examination was made of every specimen together with photomicrographs taken at 50 and 250 magnifications showing the case at each temperature and time period. A photomicrograph of each original bar was also taken, using a magnification of 500. Curves of the 1600 degree Fahr. and 1700 degree Fahr. runs were plotted for each steel on composite charts for the purpose of rapid comparison, as shown in Fig. 3 and Fig. 4.

#### Discussion of Results Shown in Curves

The steels may be divided into five general classes:

##### 1. *Straight Carbon Steels.*

The curves for these two steels are seen to be identical in shape. If one be plotted over the top of the other they are practically coincident throughout their length. The cold rolled steel is, however, considerably lower than the other. Some authorities claim that cold rolling of steel reduces its power to absorb carbon. To writer's mind, however, the principal reason for the difference in rate of penetration on these two steels may be ascribed to the increased phosphorus and sulphur content of the cold rolled stock.

##### 2. *Chromium Silico-Manganese Steels.*

In this group may be included the chromium silico-manganese and the

chromium vanadium steels. The chemical analysis of these two steels differs only in the 0.17 per cent vanadium content of the chromium vanadium steel. The curves for these two steels are coincident up to 40 hours. From 40 to 55 hours there is a very slight difference in favor of the chromium silico-manganese. These results indicate the 0.17 per cent vanadium to be without influence on penetration of carbon.

### 3. Nickel Steels.

Nickel, an element which goes into solid solution with the iron, retards penetration of carbon. This hypothesis is borne out by the data. The curve for the five per cent nickel steel lying considerably below that for the 3½ per cent nickel steel.

### 4. Chromium Nickel Steels.

The curves for these steels indicate the beneficial effects of chromium combined with nickel in aiding the penetration of carbon. The higher type 1 50 per cent chromium, 3.50 per cent nickel curve lies above the 1.00 per cent chromium 3.00 per cent nickel.

### 5. Chromium Molybdenum Steel.

The curve for this steel is in shape more like the chromium vanadium steel. It lies, however, considerably above, illustrating the helpful effect of molybdenum on the absorption of carbon.

Comparing groups 1 and 2, we notice the chromium silico-manganese

Table I  
Chemical Analysis of Steels Under Investigation

Type of Steel	C	Mn	P	S	Si	Cr	Ni	Va	Mo
Carbon Cold Rolled .....	0.15	0.72	0.103	0.092	0.015	...	...	...	...
Carbon Hot Rolled .....	0.20	0.54	0.007	0.031	0.020	...	...	...	...
Chromium Silico-Manganese .....	0.16	0.78	...	0.019	0.31	0.83	...	...	...
Chromium Vanadium .....	0.17	0.73	0.010	0.020	0.33	0.92	...	0.17	...
Nickel Steels .....	0.16	0.65	0.013	0.019	0.15	...	3.50	...	...
	0.14	0.38	0.008	...	0.095	...	5.29	...	...
Chromium Nickel .....	0.18	0.60	0.012	0.009	0.30	0.98	3.14	...	...
	0.11	0.49	0.018	0.011	0.16	1.31	3.79	...	...
Chromium Molybdenum .....	0.13	0.38	0.009	0.010	0.21	0.96	...	...	0.48

steels give deeper penetration than the straight carbon steels. This difference is no doubt due mainly to the presence of 1 per cent chromium. Looking at group 3 we see that the rate of penetration for 3½ per cent nickel steel is greater than the straight carbon and naerly as great as the chromium silico-manganese steels. The reason for this is that although nickel has a retardent action on carbon penetration, the critical temperatures for nickel steel are 100 degrees Fahr. lower. At 1700 degrees Fahr. nickel steel is therefore at a higher heat above its critical point. We should more properly compare the 1600 degree Fahr. runs for nickel with the 1700 degree Fahr. for the others. The curves for the chrome nickel steels are considerably higher than any of the others excepting the chromium molybdenum steel.

Inasmuch as the chromium vanadium of group 2 and the 1.00 per cent chromium 3.00 per cent nickel of group 4 differ only in the presence of nickel in the group 4 steel, it seems that nickel in the presence of chromium has a beneficial effect on carbon penetration, greater than chromium alone.

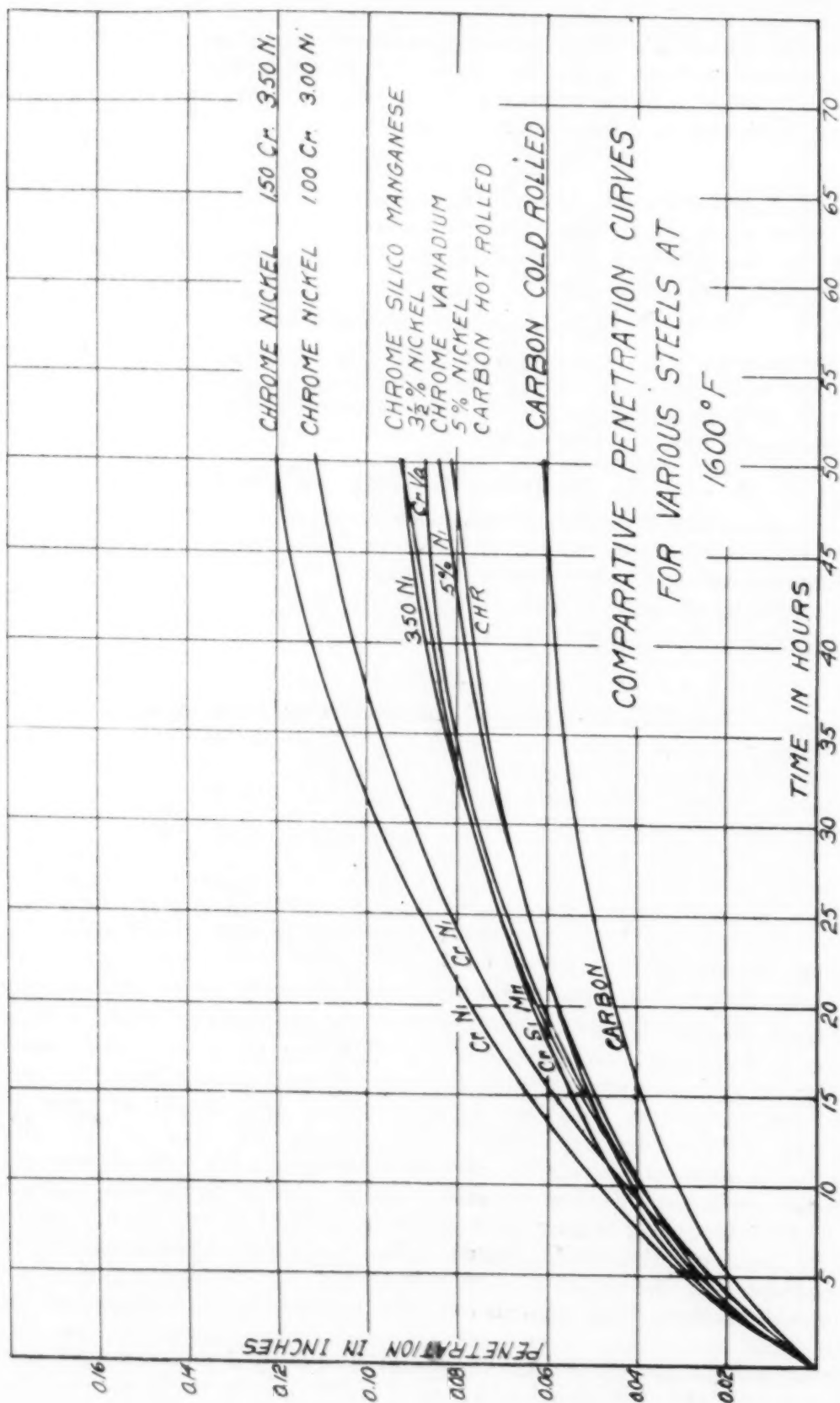


Fig. 3 Comparative carbon penetration curves for various steels subjected to a temperature of 1600 degrees Fahr.





### Microstructure

A complete series of photomicrographs were made of the original bar of each steel and the case after each time-temperature period. Inclusions of all the photos in this paper would make it very voluminous and not add greatly to its usefulness. Due to the fact that space does not permit of the reproduction of all of the photomicrographs which were made during this investigation the writer has selected one photomicrograph of the bar as received and two each of the 5, 25 and 50 hour periods at 1600 and 1700 degrees Fahr. These photomicrographs are shown in Figs. 5 to 136 inclusive.

#### *Group 1 Straight Carbon Steels*

Considering just the straight carbon cold rolled steel, we notice that it is an impure steel high in phosphorus and sulphur. This is borne out by the numerous slag and sulphide inclusions showing in the original bar and in the case and core of the different specimens. After 5 hours at 1600 degrees Fahr. the case produced is comparatively thin being between 1/64th and 1/32nd of an inch deep and mainly eutectoid in character, made up of pearlite grains. There is a thin area of cementite network structure present at the outer surface.

Twenty five hours at 1600 degrees Fahr. produces a case in the neighborhood of 3/64ths of an inch in thickness, mainly eutectoid, with a slight layer of free cementite at the edge in network areas.

Fifty hours at 1600 degrees Fahr. produces approximately a 1/16th inch case. Here the cementite network in the outer zone is more pronounced.

At 1700 degrees Fahr. a case of an entirely different character is produced. Near the outer surface a hyper-eutectoid zone is formed, made up of coarse cementite network structure surrounding pearlite grains. This is followed by a eutectoid and hypo-eutectoid zone similar to the 1600 degree Fahr. run. The zone of excess cementite is relatively light, not over 0.008 to 0.010 inches in depth and could be ground off the finished part leaving a deeper eutectoid case than is obtained after 5 hours at 1600 degrees Fahr.

After 25 hours at 1700 degrees Fahr. we greatly increase the depth of the zone containing free cementite network which covers a deep eutectoid and hypo-eutectoid zone. At 50 hours we have produced a very deep case of approximately 3/32 inch but, at the same time greatly increasing the depth of the area of cementite network. One specimen not shown in photomicrographs, was run for 24 hours at 1700 degrees Fahr. The effect of slag and nonmetallic impurities in breaking up the continuity and uniformity of the case was clearly observed. Near the center a streak of segregated impurities was observed to run out to the surface of the metal. This area resisted the penetration of carbon and caused a soft spot at that point. The effect of the higher heat was to produce a deeper case, but one containing a deeper and more coarse cementite network structure. Figs. 13 to 28 inclusive illustrates the structures observed in the cold rolled steels as carburized and as carburized and quenched.

The structure of the original bar of straight carbon hot rolled steel, Fig. 6, is seen to be ferrite and pearlite with absence of the slag and sulphide areas which were present in the impure cold rolled steel.

Figs. 29 to 44 show the microstructures observed after the carburizing tests of the hot rolled steel. Five hours at 1600 degrees Fahr. is seen to give a case a little better than 1/32 inch in depth, with a rather thin zone of cementite network. Comparison with the cold rolled steel shows the much

deeper case which is obtained on this steel in the same time at temperature. Twenty five hours at 1600 degrees Fahr. produces a deeper case with a deeper hyper-eutectoid layer. In 50 hours we have produced a 5/64ths inch case made up of distinct hyper-eutectoid, eutectoid and hypo-eutectoid zones. At 1700 degrees Fahr. the case increases in depth and the cementite network areas become thicker and the grains larger.

We see that in the plain carbon steels the case produced is characterized by an outer layer of coarse cementite network structure, followed by an eutectoid and hypo-eutectoid zone, the depth and coarseness of structure being a function of time and temperature. In treating carburized parts frequently they are cooled in the box as were these specimens, then subjected to a single reheat and quenched to refine and harden the case. When a coarse cementite network structure is present a single low heat will not break it up and we will have a brittle spalling case. It is necessary for refinement to first quench from a high enough heat to take the cementite into solution then refine the grain by a second low quench. The photomicrographs show that the alloy steel under the same conditions take a structure which may be more easily refined. We will now pass to the first of the so-called alloy steels.

#### *Group 2, Chromium Silicon Manganese and Chromium Vanadium Steels.*

Examination of the photomicrographs of this group Figs. 45 to 76 inclusive shows the structures to be of a different character than the straight carbon steels. The enormous pearlite grains of the latter group are now absent. Carburizing at heats up to 1700 degrees Fahr. has little effect on the grain size. The cementite network structure is absent and we find the excess carbides occurring as globules uniformly distributed through the hyper-eutectoid zone. The penetration of carbon at the same time is much greater. Comparing the chromium silicon manganese and the chromium vanadium steels we see that the vanadium, although not affecting the rate of penetration, has a beneficial effect in producing a denser, more finely divided structure.

#### *Group 3. Nickel Steels*

In the 3½ per cent nickel steel, photomicrographs of which are shown in Figs. 77 to 92 inclusive we find the excess carbide occurring as small globules and a fine network surrounding the grains. At 1700 degrees Fahr. the structure appears to be somewhat coarsened but not badly overheated. The 5 per cent nickel steels, photomicrographs of which are shown in Figs. 93 to 108 inclusive are approaching the air hardening range of steels. In the high carbon zone the structure is made up of coarse martensite with patches of austenite. As the carbon gets lower we pass into troostite, sorbite and pearlite. No network structure is found, and what carbide is visible appears to be distributed as small globules.

#### *Group 4. Chromium Nickel Steel*

In the case of the chromium nickel steel, when the carbon content is raised by carburizing, it becomes air hardening. The structures as cooled in the boxes, show austenite and martensite passing to troostite, sorbite and pearlite as we approach the core. Photomicrographs of this series is shown in Figs. 109 to 126 inclusive. At the very edge there appears a layer of excess carbides mostly as globules, as though the steel had absorbed the carbon more rapidly than it could diffuse it and take it into solution. This steel



has a strong tendency toward a streaky structure and this tendency of the bar is carried into the case where it is necessary to eliminate it by proper heat treatment.

#### *Group 5. Chromium Molybdenum Steel*

The carburized zones in this steel, shown in Figs. 127 to 136 inclusive, are more on the order of the chromium silico-manganese steel. The cementite in the hyper-eutectoid zones occurs as large globules as in the chromium silico-manganese steel, but there is also considerably more of the large network structure present than in any of the other alloy steels. In this respect this steel approaches the straight carbon steel structures.

#### **Effect of Heat Treatment**

The heat treatments which were used were taken from S.A.E. Recommended Practice and were applied to specimens which were carburized for the 50-hour run at 1700 degrees Fahr.

#### *Group 1—Straight Carbon Steel.*

Single treatment—Heat to 1475 degrees Fahr. quench in water.

Double treatment—Heat to 1585 degrees Fahr. quench in oil; reheat 1425 degrees Fahr., quench in water.

The effect of the double treatment as compared to the single is seen to be in much greater core refinement, Figs. 25, 26, 27, 28, 41, 42, 43 and 44, and in causing some diffusion and solution of the outer cementite network.

#### *Group 2—Chromium Silico-Manganese and Chromium Vanadium Steels.*

Single treatment CrSM 1475 degrees Fahr., quench in water.

Single treatment Cr Va. 1525 degrees Fahr., quench in water.

Double treatment CrSM 1585 degrees Fahr., quench in oil; reheat to 1425 degrees Fahr., quench in water.

Double treatment Cr Va. 1675 degrees Fahr., quench in oil; reheat to 1475 degrees Fahr., quench in water.

Figs. 57, 58, 59, 60, 73, 74, 75 and 76 show photomicrographs of these steels revealing greater refinement of case and core with single treatment than do the straight carbon steels. The chromium vanadium steel shows a more dense uniform case. The thickness of the excess carbide zone is greater but there is complete absence of any network.

#### *Group 3—Nickel Steels—3½ Per Cent and 5 Per Cent*

Single treatment—3½ per cent Nickel heat to 1475 degrees Fahr., quench in water.

Double treatment—3½ per cent Nickel heat to 1525 degrees Fahr., quench in oil. Reheat to 1350 degrees Fahr., quench in water.

Single treatment—5 per cent Nickel heat to 1475 degrees Fahr., quench

Single treatment—5 per cent Nickel heat to 1475 degrees Fahr., quench

Double treatment—5 per cent Nickel heat to 1500 degrees Fahr., quench in oil. Reheat to 1300 degrees Fahr., quench in water.

The case and core of both these steels appear absolutely uniform after either single or double treatment as shown in Figs. 89, 90, 91, 92, 105,

106, 107 and 108. No trace of excess cementite as in the other steel is visible here. The double treatment gives a more refined core and case than the single treatment.

#### *Group 4—Chromium Nickel Steel.*

Single treatment—heat to 1500 degrees Fahr., quench in oil.

Double treatment—heat to 1600 degrees Fahr., quench in oil; reheat 1425 degrees Fahr., quench in oil.

This steel shows a dense fine grained core and case after either treatment as shown in Figs. 123, 124, 125 and 126. The structure after double treatment however, appears somewhat more refined and uniform. Some of the excess carbide is visible at the edge but there is an entire absence of network structures.

#### *Group 5—Chromium Molybdenum Steel*

Single treatment—heat to 1500 degrees Fahr., quench in water.

Double treatment—Heat to 1600 degrees Fahr., quench in oil; reheat to 1475 degrees Fahr., quench in water.

This steel does not lend itself to refinement of case by either single or double treatment. The core apparently becomes well refined by either. The case is better after double treatment but in either condition has altogether too much of the network structure. This would make a very brittle part. The photomicrographs of this type of steel is shown in Figs. 133 to 136 inclusive.

### **Conclusions**

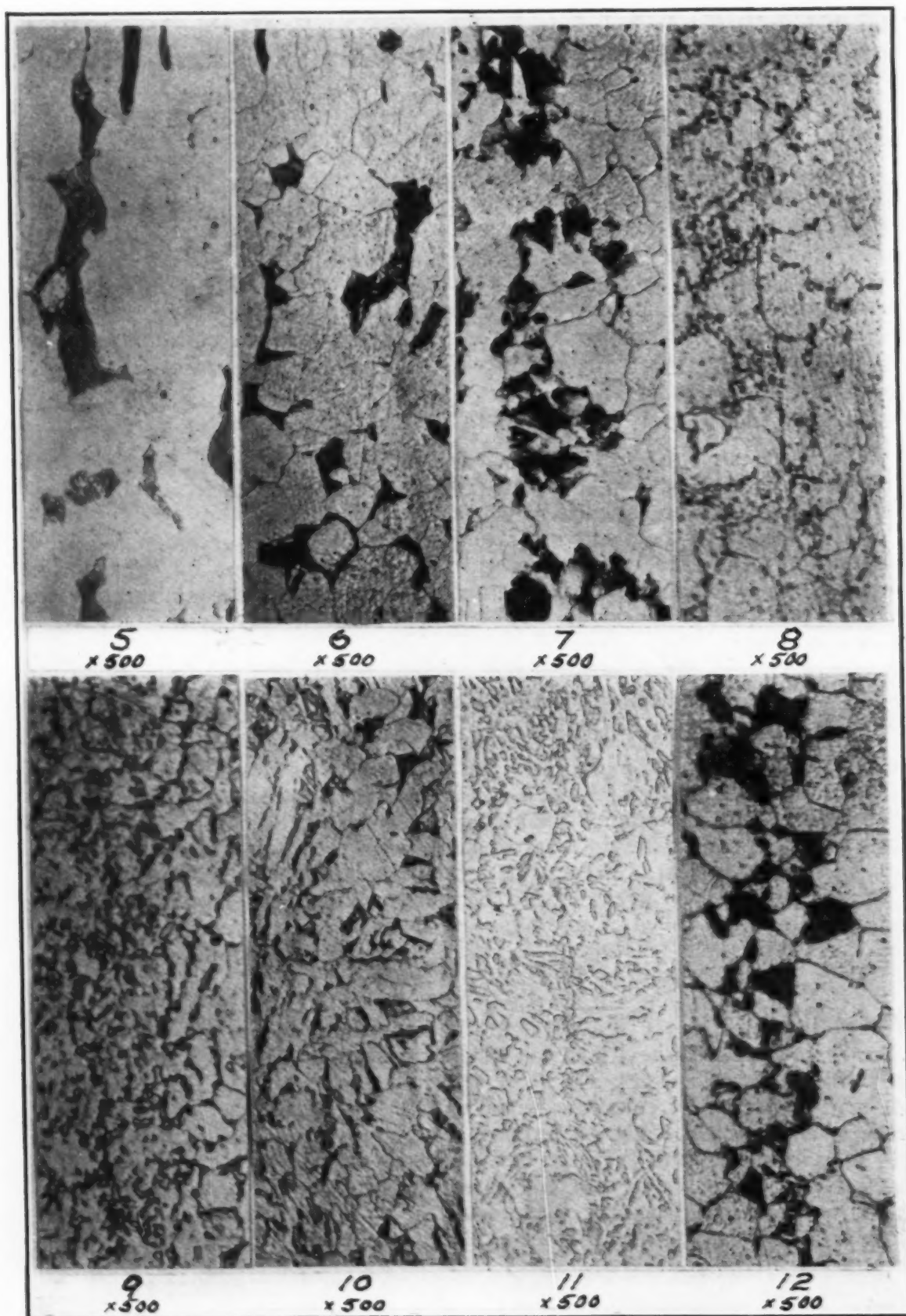
In summing up, the writer wishes to say that the work that has been done in this investigation indicates the superiority of the Chromium Nickel and Chromium Molybdenum steels insofar as rate of penetration of carbon is concerned. The Chromium Vanadium and Chromium Silico-Manganese steels come next, then the Straight Carbon steels, with the Nickel steels last.

This would indicate Nickel to be a retarding agent when present alone but a helping agent when present with Chromium. The difference between the cold rolled and hot rolled Straight Carbon steels shows the retarding effects of high phosphorus and sulphur. We find Vanadium in percentages of 0.17 to be of no effect on rate of penetration of carbon.

From the standpoint of microstructure the work indicates the superiority of the alloy steels over the Straight Carbon steels. They are more easily refined by single treatment and much superior after double treatment. Chromium Molybdenum steel appears to be an exception to this in that its case is not readily refined by either single or double heat treatment; in fact a good grade of carbon steel seems preferable.

In selecting a steel for case hardening, therefore, it is very evident that many factors must be considered. The writer sincerely hopes that the research work he has done as evidenced by the data included in this paper may serve as a guide as to what is to be expected in the way of the rate of carbon penetration in the commercial steels.

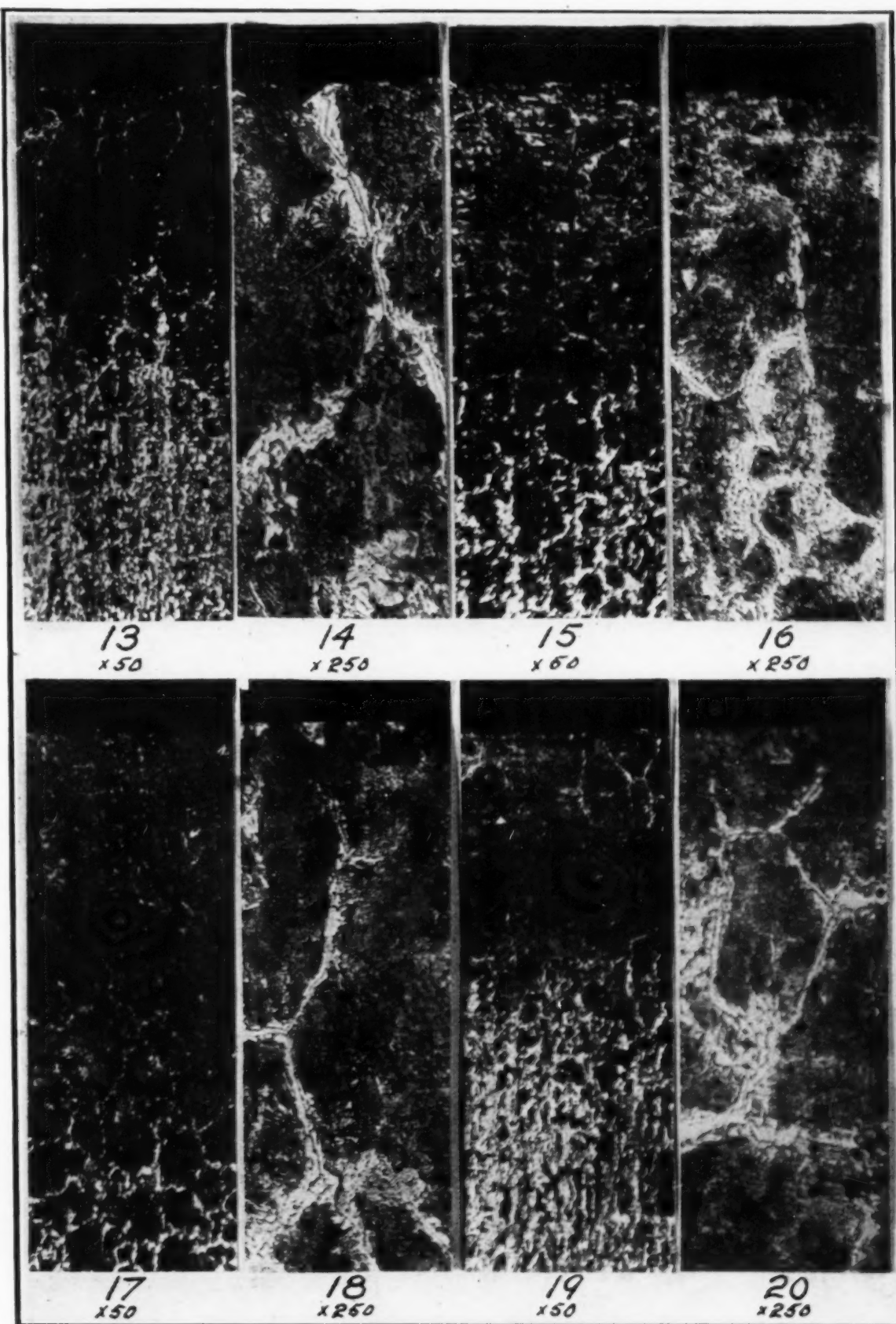
*The photomicrographs obtained in this research follow on pages 960 to 976 inclusive.*



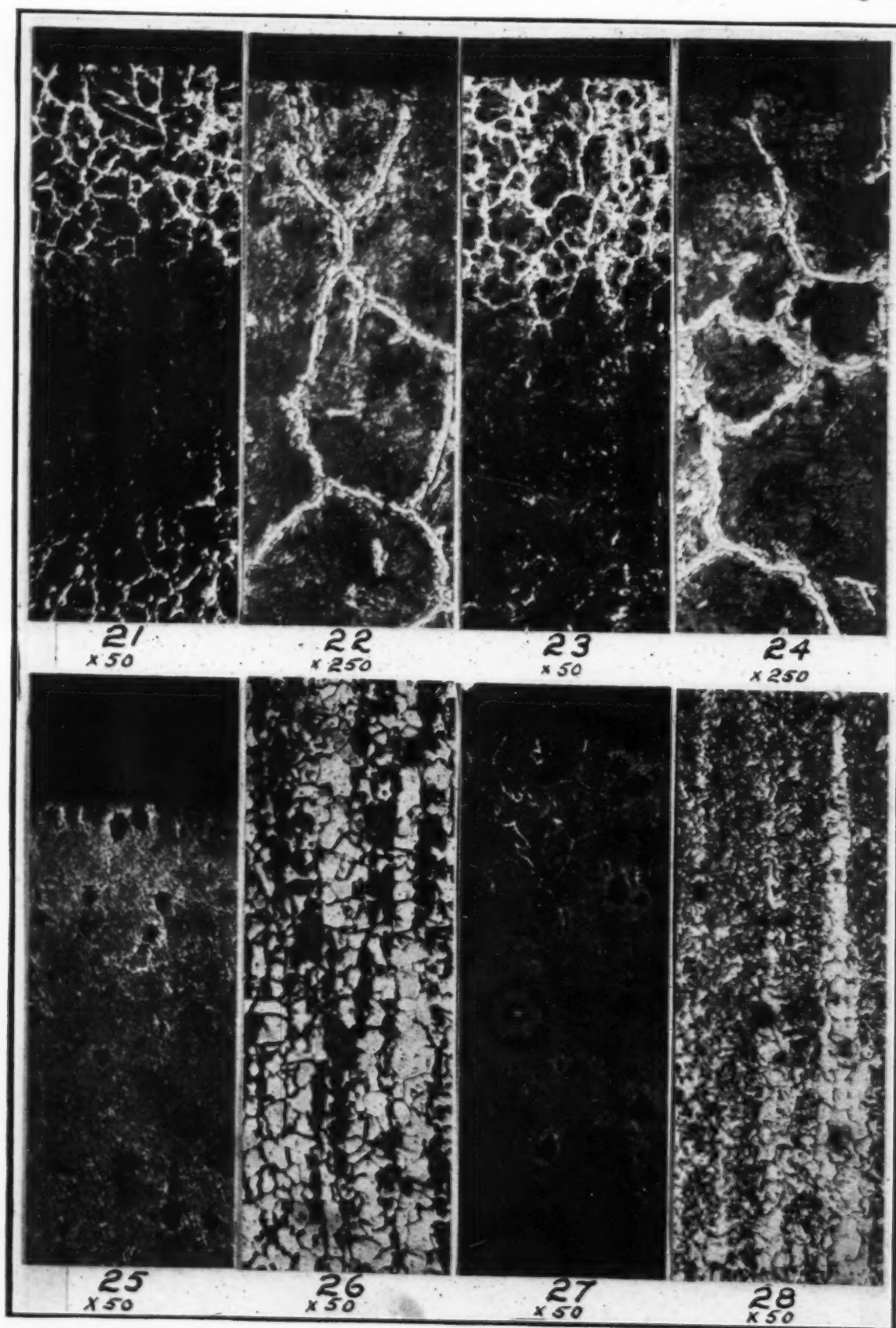
## ORIGINAL BAR STEEL STRUCTURE AS RECEIVED

Fig. 5 Cold Rolled Steel Showing the Presence of Non-metallic Inclusions. Fig. 6 Hot Rolled Steel. Fig. 7 Chromium Silicon Manganese Steel. Fig. 8 Chromium Vanadium Steel. Fig. 9 Three and one half Per cent Nickel Steel. Fig. 10 Five Per cent Nickel Steel. Fig. 11 Chromium Nickel Steel. Fig. 12 Chromium Molybdenum Steel.



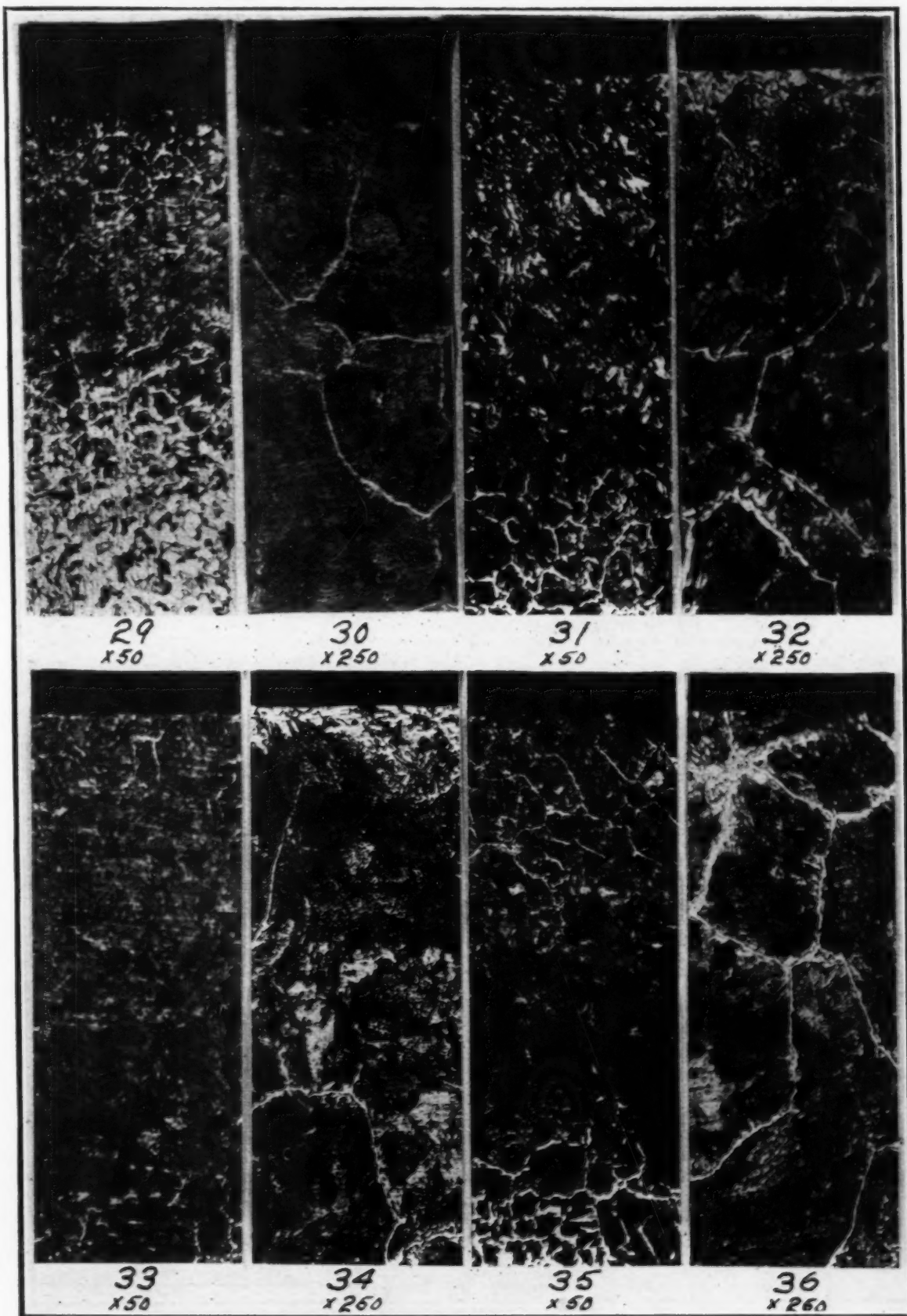
**COLD ROLLED CARBON STEEL**

Figs. 13 and 14, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 15 and 16, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 17 and 18, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. It will be noticed that the case in each specimen is mainly eutectoid in character with a slight cementite network near the outer surface. About 1/16 inch case was obtained after 25 hours. Figs. 19 and 20, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr.

**COLD ROLLED CARBON STEEL**

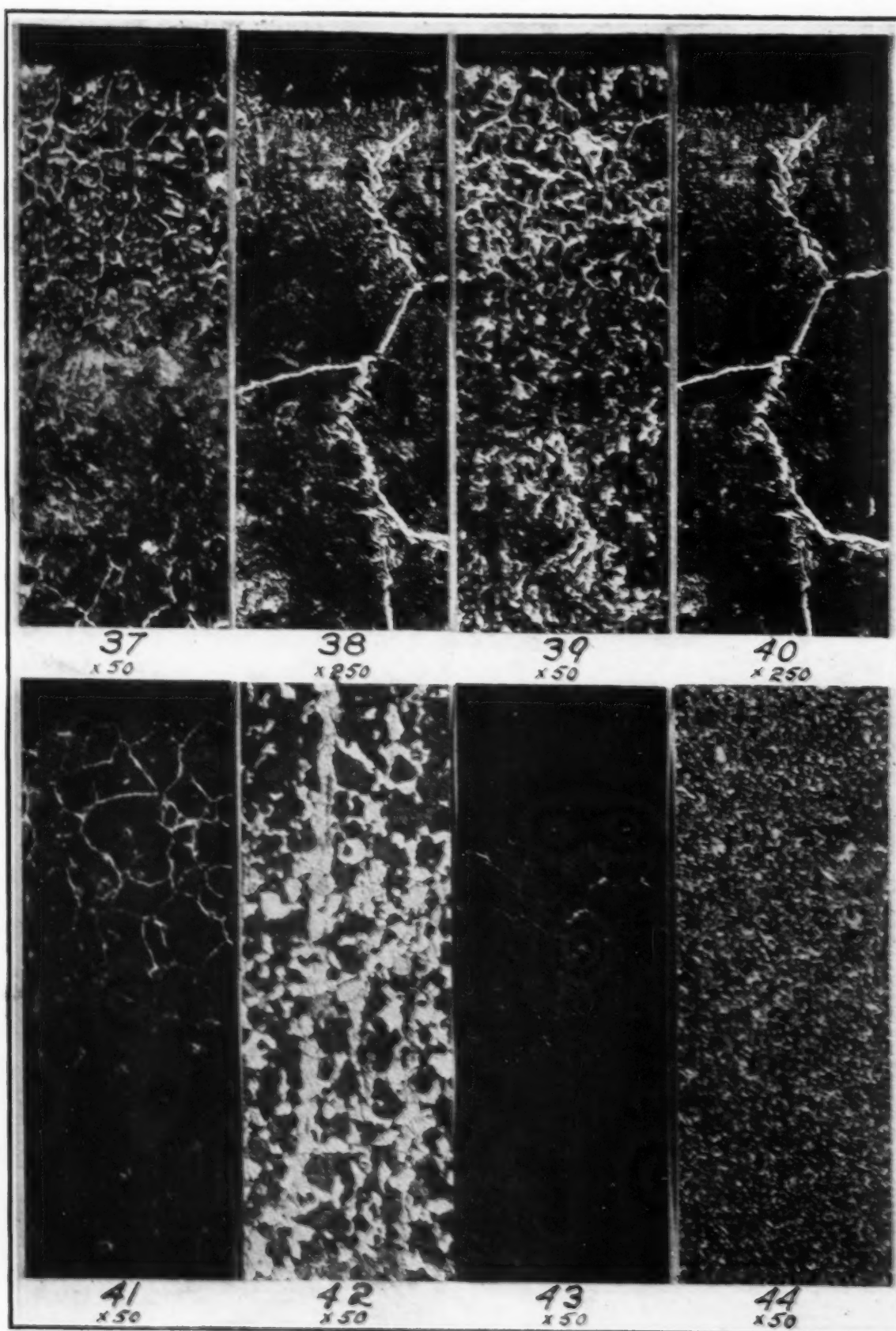
Figs. 21 and 22, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 23 and 24, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. The outer surface hyper-eutectoid zone will be noticed in each of these specimens heated at 1700 degrees Fahr. Figs. 25 and 26, show the heat treated structure of case and the core of specimens carburized at 1700 degrees for 50 hours. Specimens were heated to 1475 degrees Fahr. and water quenched. Figs. 27 and 28, having same carburizing treatment were quenched in oil from 1585 degrees Fahr. and reheated and quenched in water from 1425 degrees Fahr.



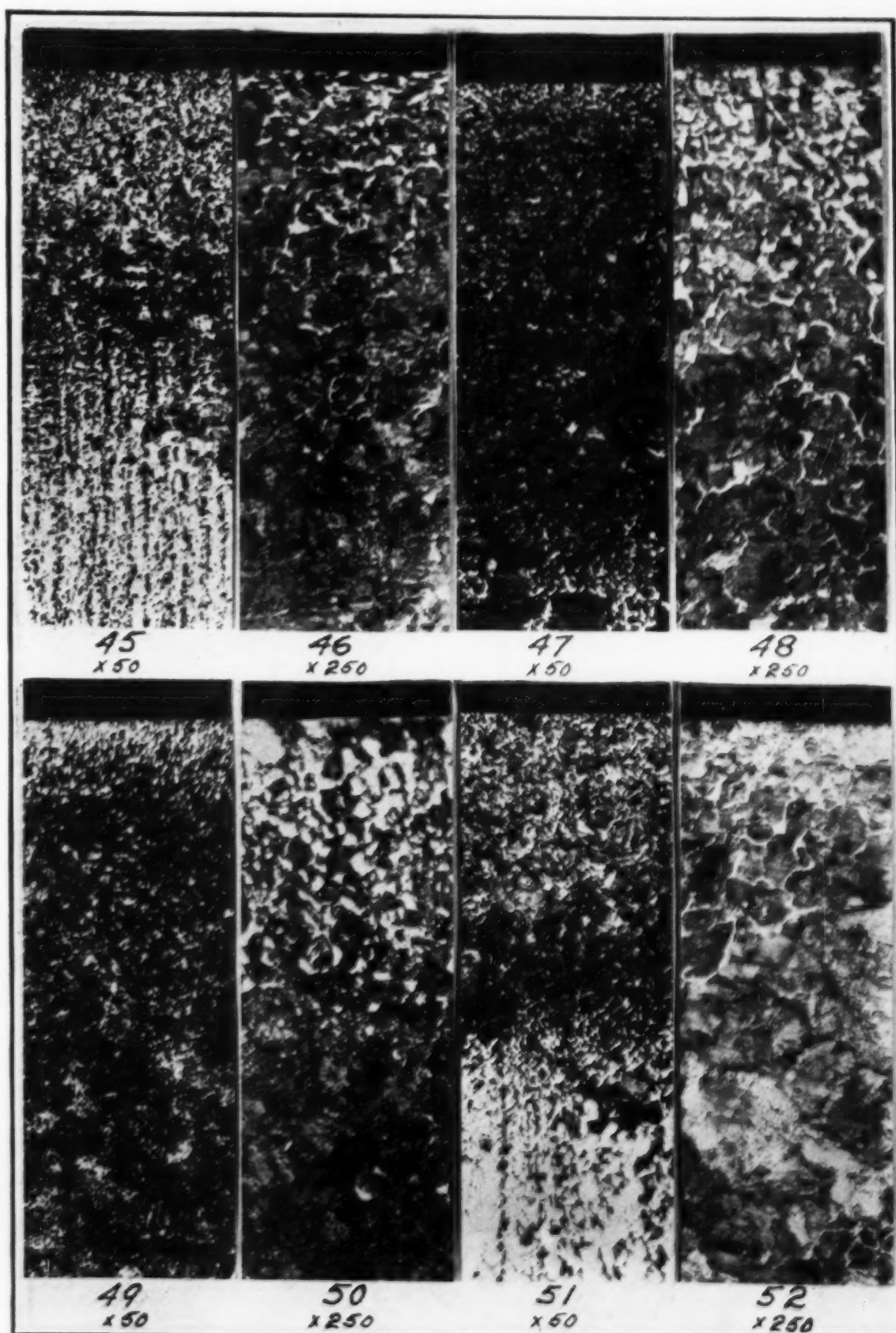
**HOT ROLLED CARBON STEEL**

Figs. 29 and 30, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 31 and 32, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 33 and 34, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 35 and 36, microstructure of specimens carburized for 5 hour at 1700 degrees Fahr. Note the increasing hyper-eutectoid layer as the time and temperature increases.



**HOT ROLLED CARBON STEEL**

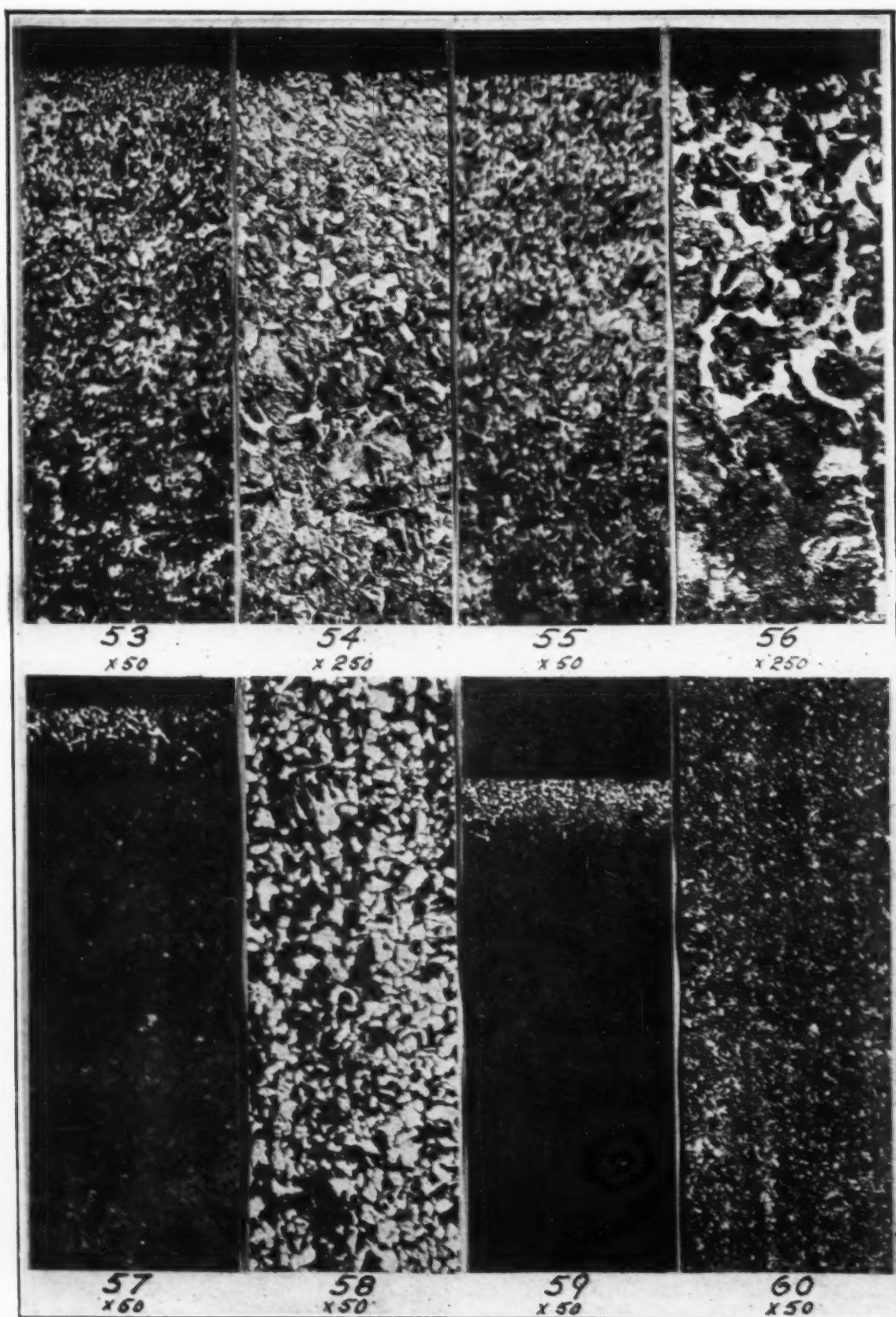
Figs. 37 and 38, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 39 and 40, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. In 50 hours a  $5/64$  inch case has been produced made up of distinct hyper-eutectoid, eutectoid and hypo-eutectoid zones. Figs. 41 and 42, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1475 degrees Fahr. Figs. 43 and 44, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1585 degrees Fahr. and reheated and quenched in water from 1425 degrees Fahr.



## CHROMIUM SILICON MANGANESE STEEL

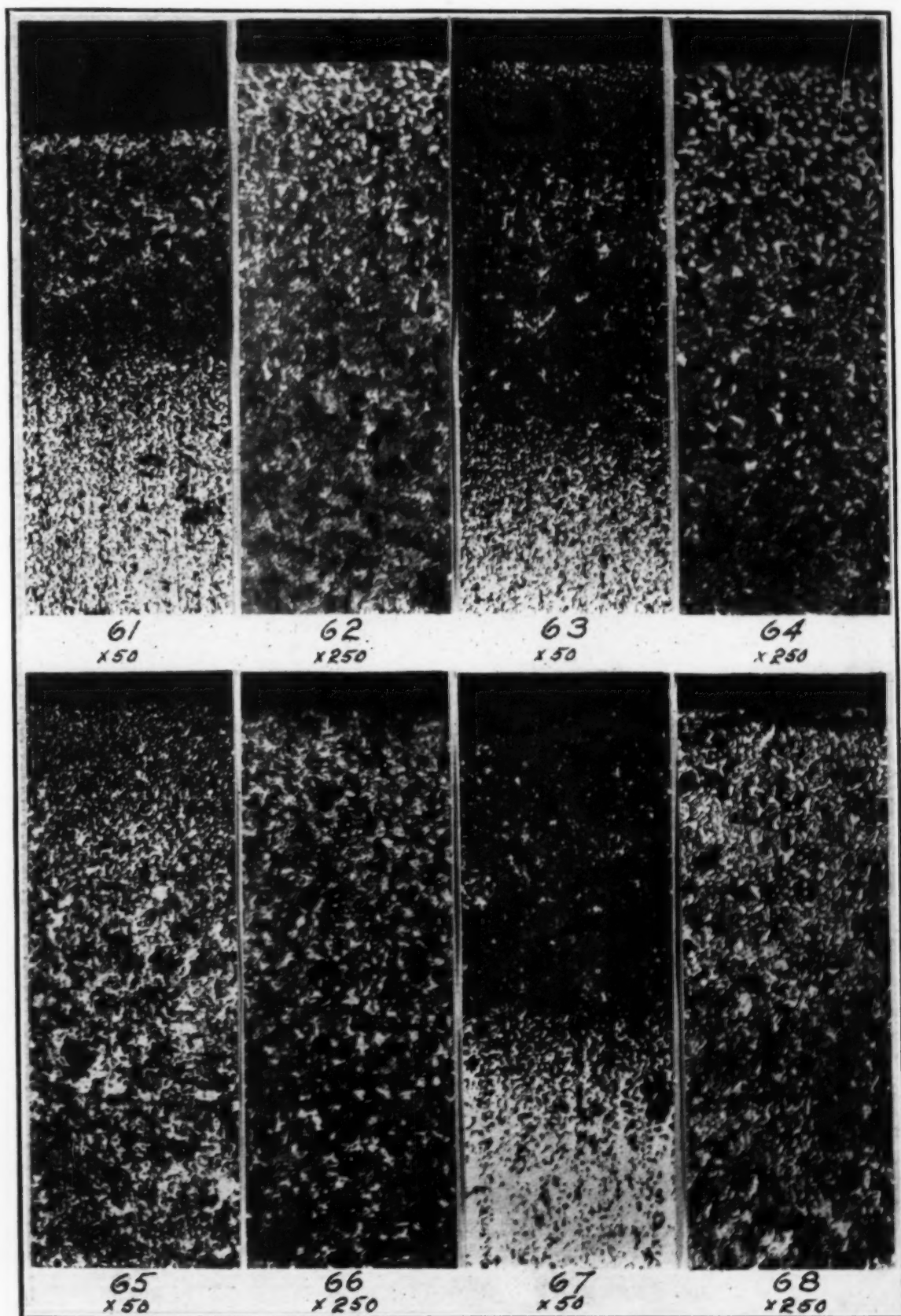
Figs. 45 and 46, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 47 and 48, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 49 and 50, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 51 and 52, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Note that the large pearlite grains of the carbon steel series is now absent.



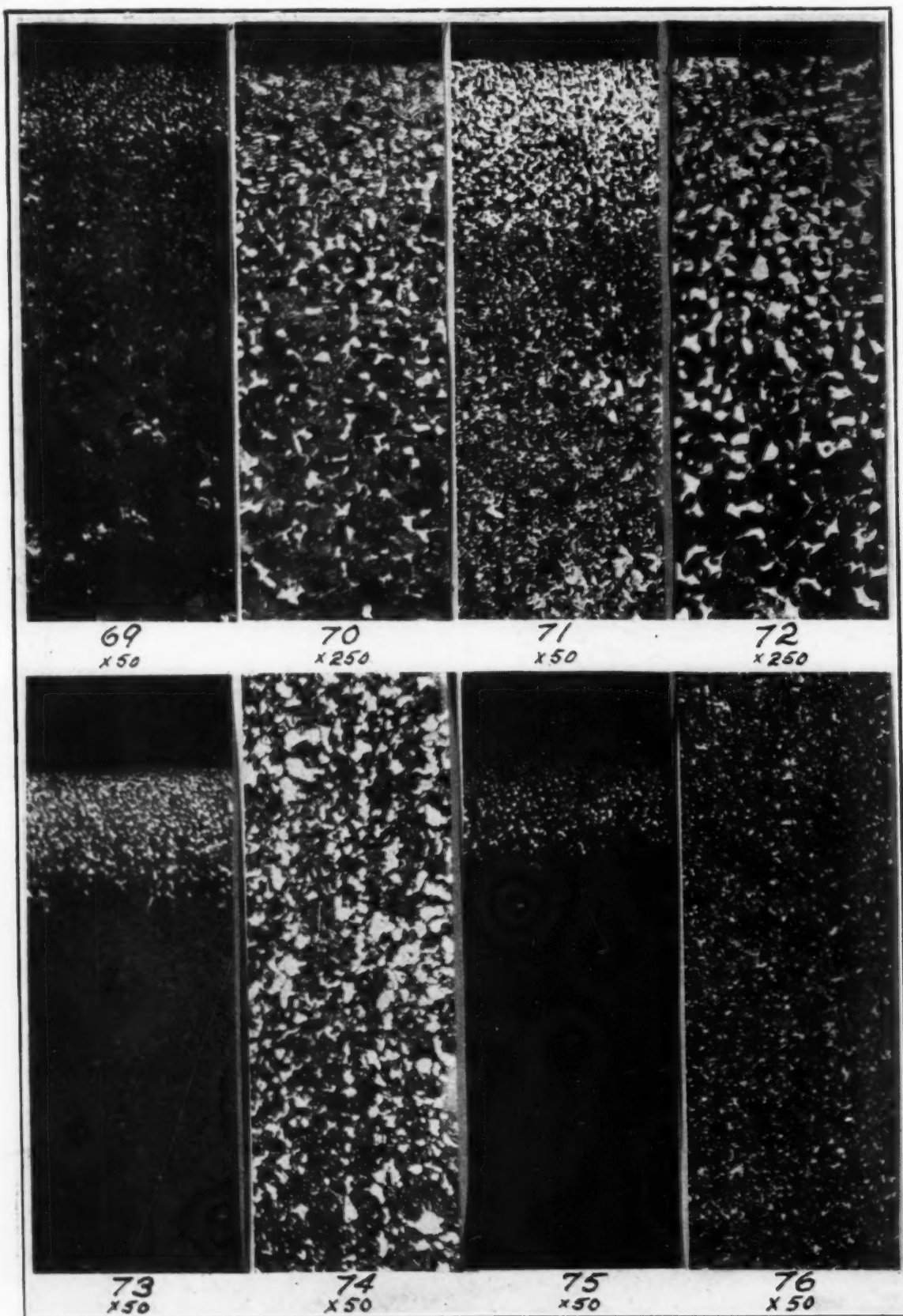
**CHROMIUM SILICON MANGANESE STEEL**

Figs. 53 and 54, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 55 and 56, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Note that the cementite network structure is absent in these specimens. Figs. 57 and 58, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1475 degrees Fahr. Figs. 59 and 60, case and core microstructure of 50 hours specimens carburized at 1700 degrees Fahr. quenched in oil from 1585 degrees Fahr. reheated and quenched in water from 1425 degrees Fahr.



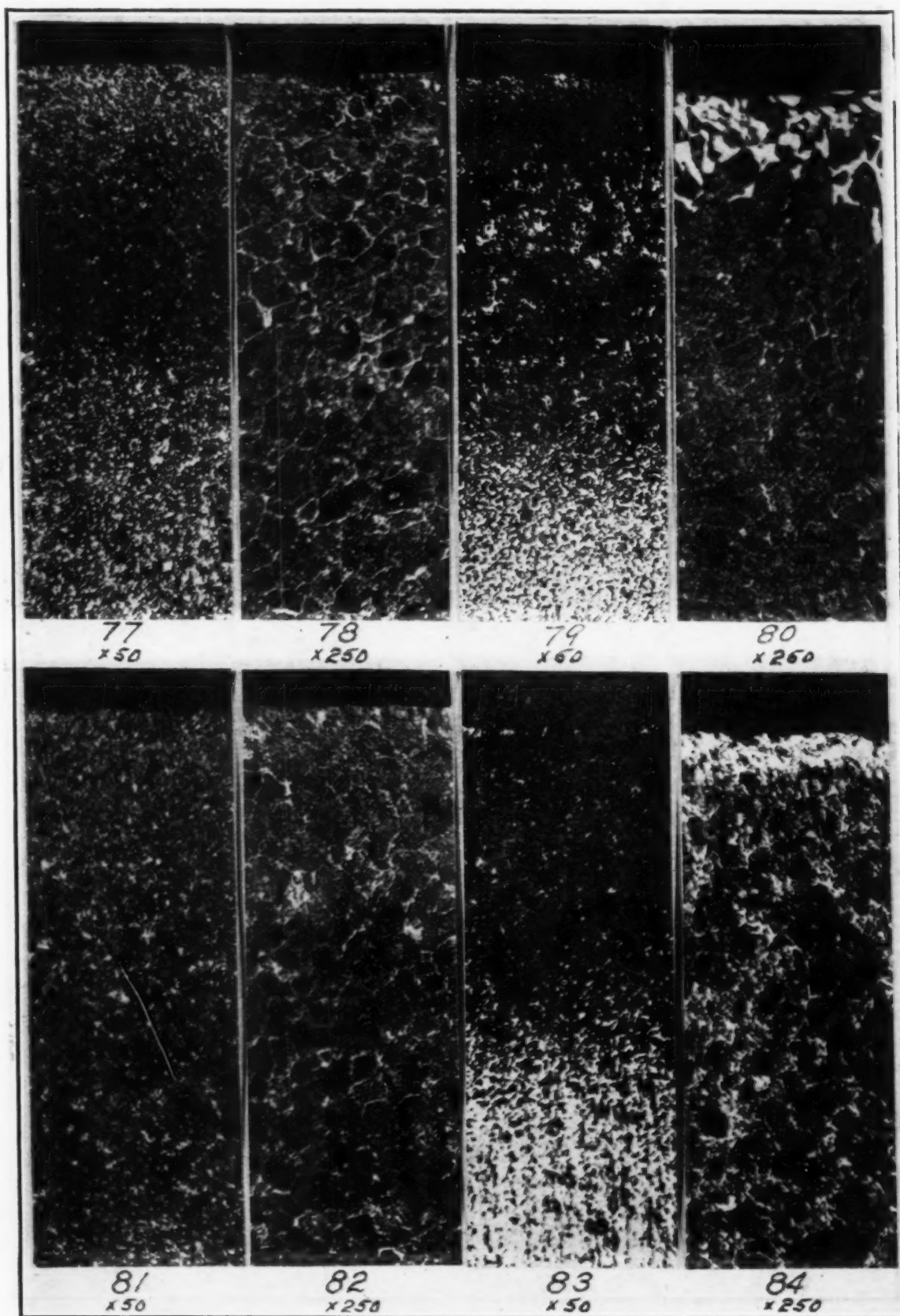
**CHROMIUM VANADIUM STEEL**

Figs. 61 and 62, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 63 and 64, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 65 and 66, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 67 and 68, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Vanadium produces a dense finely divided structure.

**CHROMIUM VANADIUM STEEL**

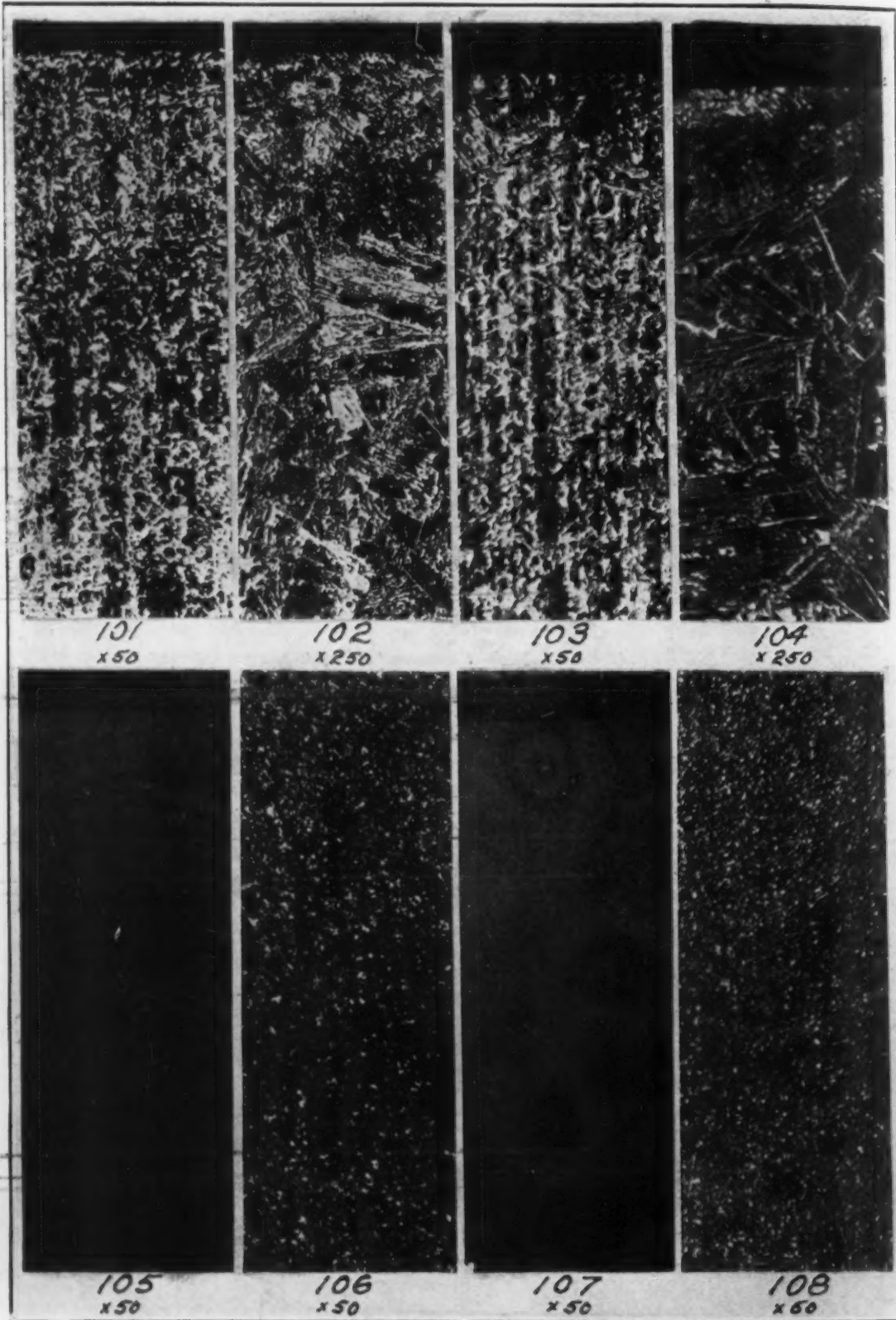
Figs. 69 and 70, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 71 and 72, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. We find the excess carbides occurring as globules uniformly distributed through the hyper-eutectoid zone. Figs. 73 and 74, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1525 degrees Fahr. Figs. 75 and 76, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1675 degrees Fahr., reheated and quenched in water from 1475 degrees Fahr.



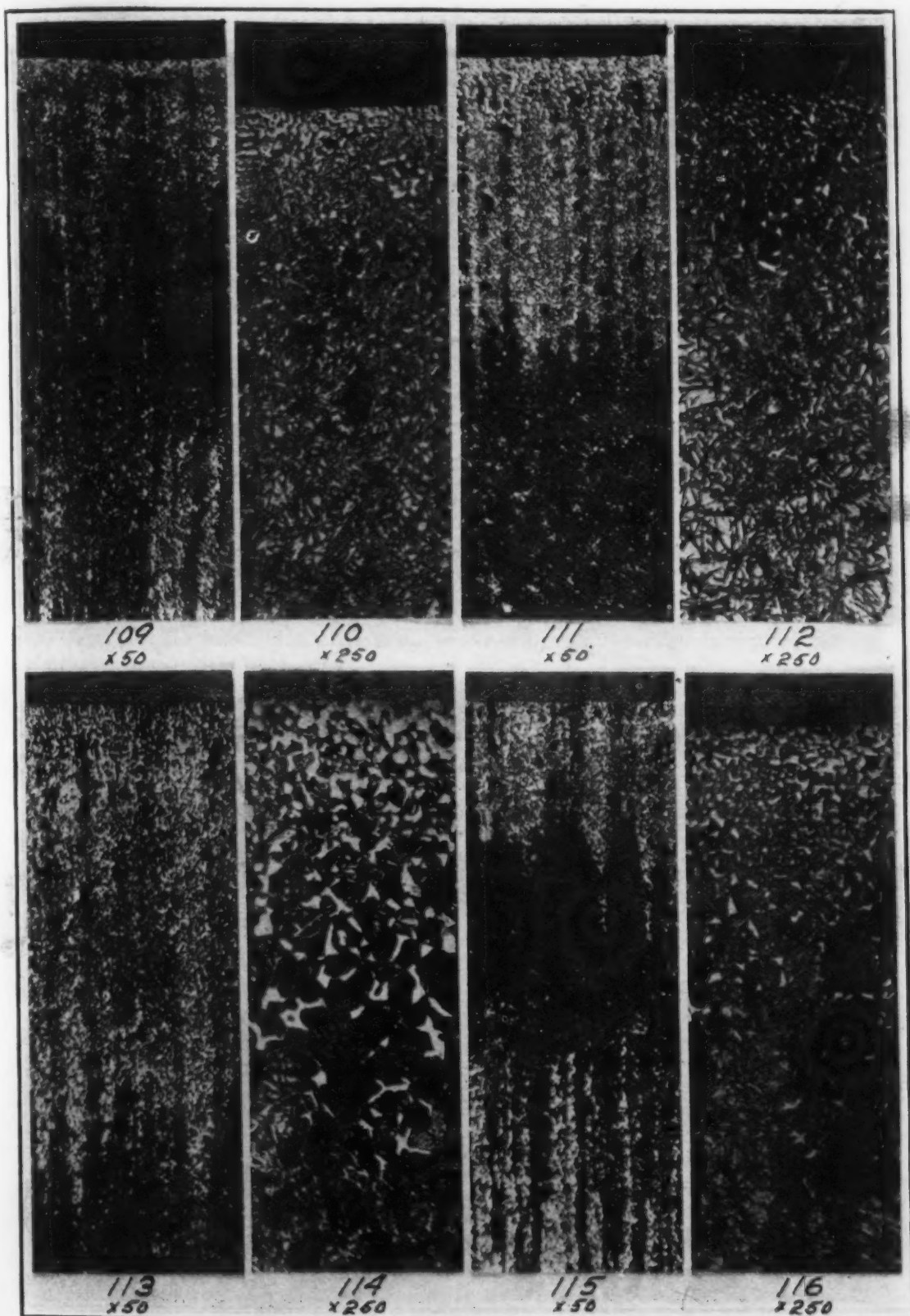
**NICKEL STEEL—3½ PER CENT**

Figs. 77 and 78, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 79 and 80, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 81 and 82, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 83 and 84, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Excess carbides occur as small globules and a fine network surrounding the grains.

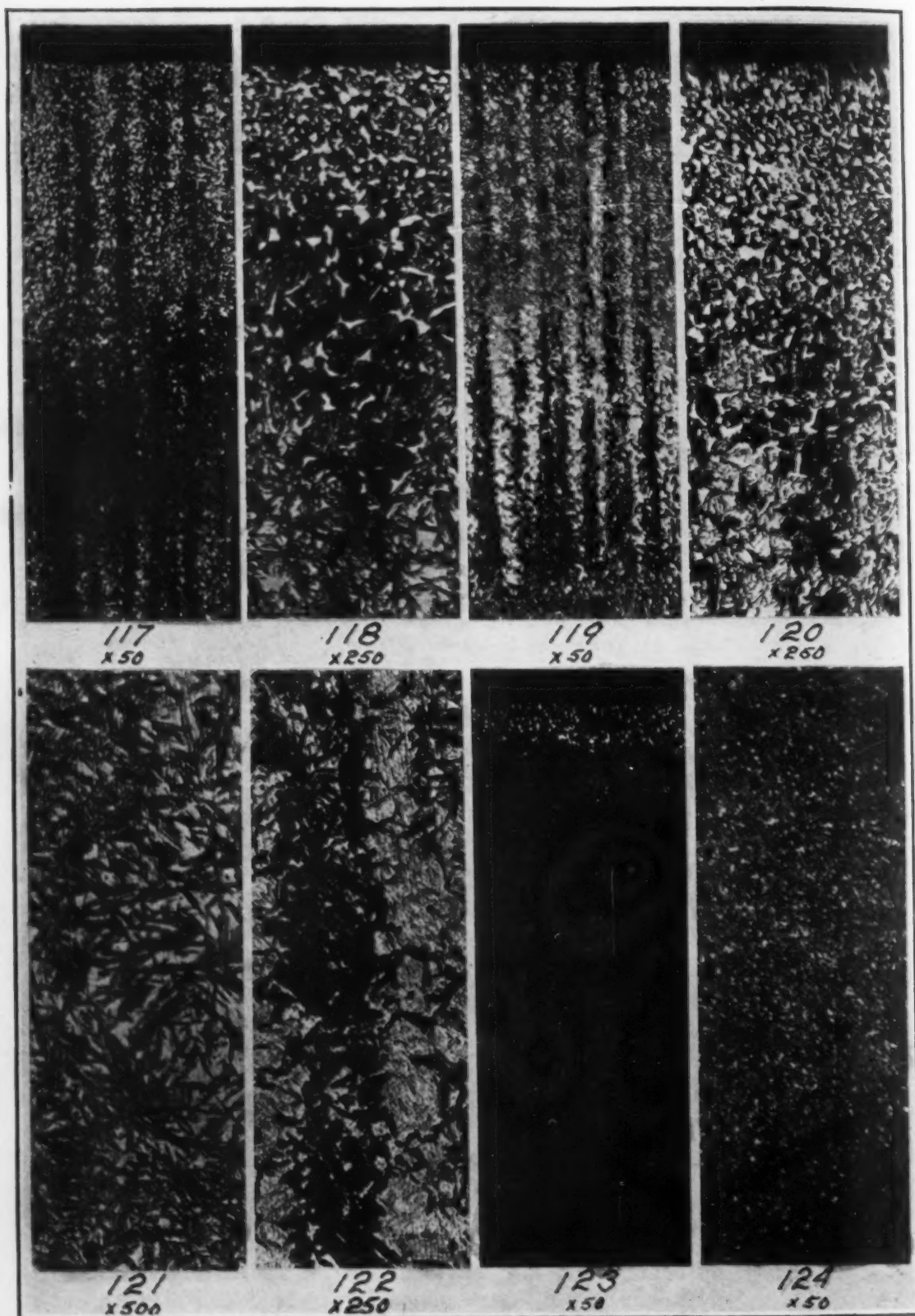


**NICKEL STEEL—5 PER CENT**

Figs. 101 and 102, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 103 and 104, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Figs. 105 and 106, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1475 degrees Fahr. Figs. 107 and 108, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1500 degrees, Fahr. reheated and quenched in water from 1300 degrees Fahr.

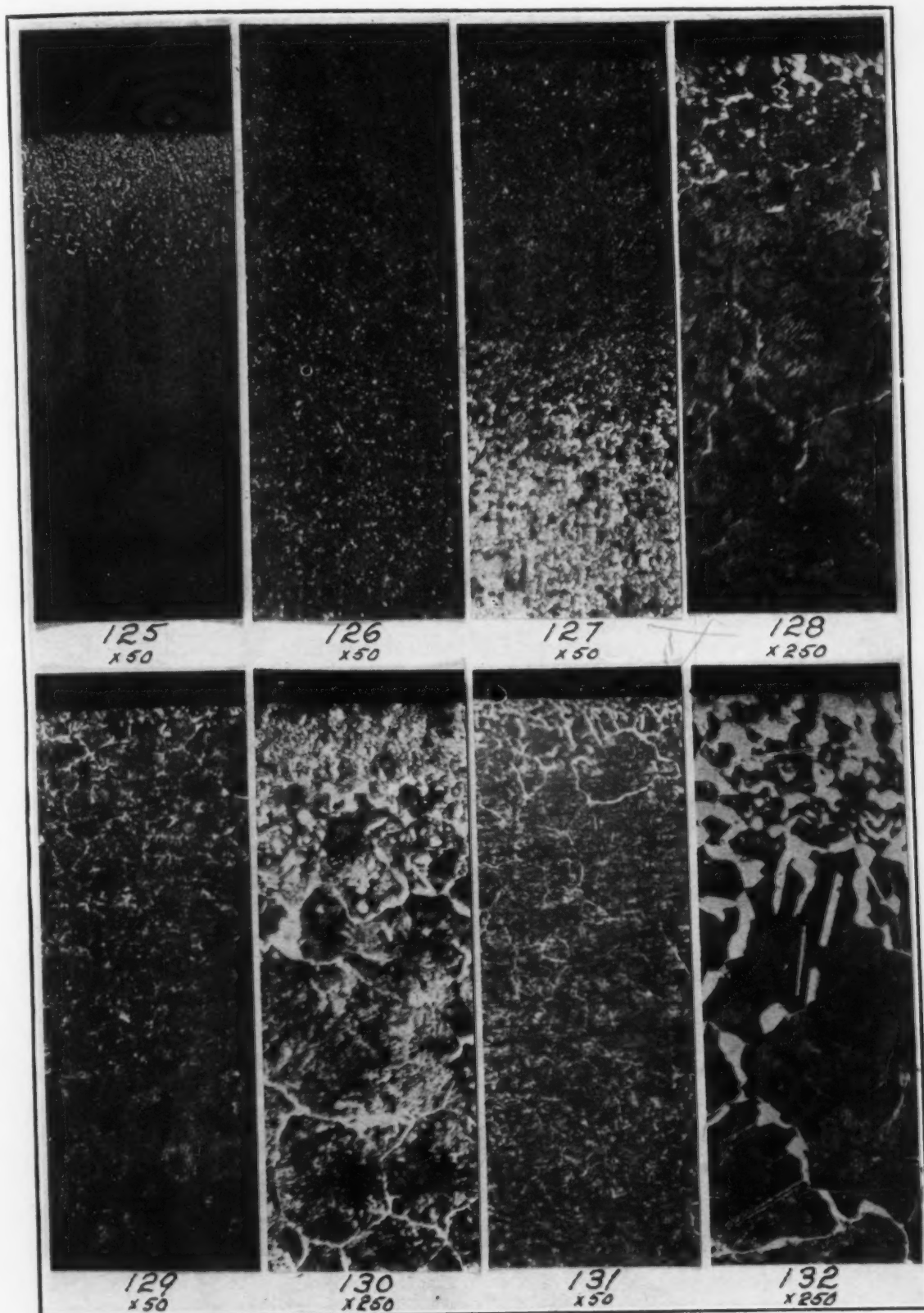
**CHROMIUM NICKEL STEEL**

Figs. 109 and 110, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 111 and 112, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 113 and 114, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 115 and 116, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Specimens cooled in the boxes show structures of austenite and martensite passing to troostite, sorbite and pearlite as the core is approached.

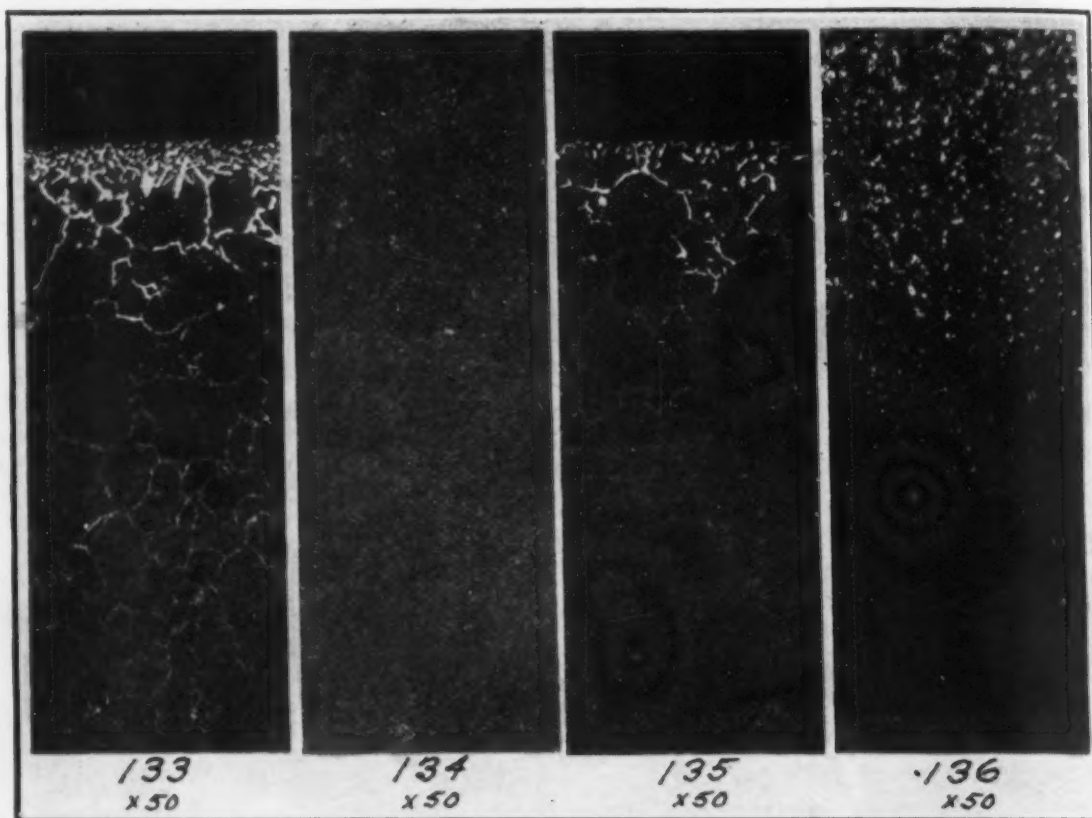
**CHROMIUM NICKEL STEEL**

Figs. 117 and 118, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 119 and 120, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Figs. 121 and 122, microstructure of martensite and troostite, respectively. Figs. 123 and 124, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched from 1500 degrees Fahr. in oil. Chrome Nickel steels have a strong tendency toward a streaky structure.



**CHROMIUM MOLYBDENUM STEEL**

Figs. 125 and 126, chromium nickel steel case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1600 degrees Fahr. reheated and quenched in oil from 1425 degrees Fahr. Figs. 127 and 128, microstructure of chromium molybdenum steel specimens carburized for 5 hours at 1700 degrees Fahr. Figs. 129 and 130, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 131 and 132, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr.

**CHROMIUM MOLYBDENUM STEEL**

Figs. 133 and 134, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1500 degrees Fahr. Figs. 135 and 136, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1600 degrees Fahr. reheated and quenched in water from 1475 degrees Fahr.

## A COILING AND HEAT TREATING PLANT FOR HELICAL SPRINGS

By William J. Merten

THE manufacture of helical springs involves the following steps:

1. Design.
2. Selection and fabrication of material.
3. Coiling.
4. Heat treatment.

The literature on this subject quite adequately treats the steps of design and selection of materials. The operations of coiling and heat treatment, however, while of equal importance has been left to the mercy of an untrained and unappreciative personnel. This condition is particularly evident in the type of control given the heat treating cycle, as an instance of this may be cited that it is now frequent practice to quench a spring immediately after it has been coiled without reheating, despite the fact that the benefits obtainable from the use of a correct heat treating process are well known to those skilled in the art. As a result of the prevalent comparative indifference to technical control, great variation in spring characteristics and life are the rule and not the exception. If we are to attain a high standard in spring performance, an adequate control of the metallurgical processes entering into the spring manufacture must be secured.

### Manufacture of Springs

The chief factors to be considered in the manufacture of helical springs are the following:

#### *I—Design:*

1. Magnitude of principal stresses.
  - (a) Magnitude of applied load.
  - (b) Frequency of rate of application of maximum stresses.
2. Degree of eccentricity of applied load.
  - (a) Amount of lateral displacement.
  - (b) Active number of coils.
3. Material of requisite physical properties.

#### *II—Manufacture of Spring Steel:*

1. Melting of steel and manipulation of fluid and semi-fluid material.
2. Ingot discard to eliminate pipes, segregation, chipping out seams, and other injurious surface defects.
3. Rolling of ingots into billets—cropping and chipping of billets.
4. Rolling of billets into bars and rods.

#### *III—Coiling of Springs:*

1. Predetermined uniform rate of heating of entire bars to coiling temperature.
2. Correct coiling temperature. Defined as the temperature of least resistance of the metal to plastic flow without injuring the grain structure by over-heating. This temperature is between 1700-1800 degrees Fahr. for spring steel.
3. Uniform coiling temperature over the entire length of the bar.

A paper presented before the Indianapolis Convention. The author, William J. Merten, is metallurgical engineer, Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa.



Constant pitch, uniform diameter of coils, and correct length depend upon achieving an even temperature of the bars before coiling.

The labor involved in the adjustment (after coiling) to secure uniformity of pitch and length may be avoided by following this procedure.

4. Temperature and lubrication of mandrel. The usual practice of cooling mandrel by dashing on it cold water before, during, and after coiling, should be prohibited. Warping and cracking of the mandrel and the spring may be caused by the resultant local chilling.

Since the physical properties of the mandrel steel are at their maximum at approximately 300 degrees Cent., it would be to the advantage of the manufacturer to coil the springs on a hot mandrel. To lubricate the hot mandrel the use of a heat resistant dry material such as talc has been found practical.

On the more common sizes of springs ordinary air cooling is sufficient to maintain the mandrel at approximately 300 degrees Cent. For very large and long springs the use of air blast is suggested.

It should be noted that a better spring is secured, with less distortion and less internal strains, the higher the temperature of the mandrel during the coiling process.

5. Roller type guides. It is almost universal practice to employ sliding contact guides to hold the barstock while being coiled. However, the use of roller guides greatly reduces the embedding of hard scale and surface scoring of bars, inevitable with sliding contact guides.

6. Direct motor drive of coiling machines eliminates variations in coil diameters and pitch caused when using belt drive.

7. Cooling springs after coiling:

Slow and uniform cooling of springs to approximately 600 degrees Fahr. on heat insulated slabs to prevent distortion is necessary before heat treating the material. This is advocated because it facilitates the attainment of the correct quenching temperature and soaking time required for the completion of the grain refinement.

#### *IV—Heat Treatment of Springs:*

1. Heating for quenching.

(a) Predetermined uniform rate of heating.

(b) Correct quenching temperature and uniformity of this temperature over the entire spring.

(c) Quenching equipment.

(d) Quenching method.

(e) Quenching medium.

2. Heating for tempering or drawing.

(a) Uniform rate of heating.

(b) Correct tempering or drawing temperature.

(c) Tempering medium and equipment.

(d) Time period of tempering.

#### *V—Testing of Springs:*

1. Brinell Hardness test.

2. Compression test.

### **Helical Spring Coiling and Heat Treating Plant**

1. Design of equipment.

In the design of the equipment, proper consideration must be given to the following:

(a) Quantity and quality production.

- (b) Labor saving devices and fuel conservation.
- (c) Low cost of installation.
- (d) Low cost of maintenance.

## 2. Location:

Positioning of the equipment is of prime importance as it is necessary to insure a continuous operation with a minimum amount of manual labor and avoidance of cross transportation. A very convenient and rapid production plant layout for coiling and heat treating is shown in Fig. 1.

### *Furnace For Heating Bar Stock*

The furnace shown in Fig. 2 is of the resistor type. This furnace is unique in that the heating chamber is of adjustable length, to permit obtaining maximum heating economy with either long or short bars.

The furnace is designed so that the heating chamber may be either 10 feet, 15 feet, 20 feet, 25 feet, or 30 feet long, by inserting or removing a partition every 5 feet after the first 10 feet. The heating chamber dimen-

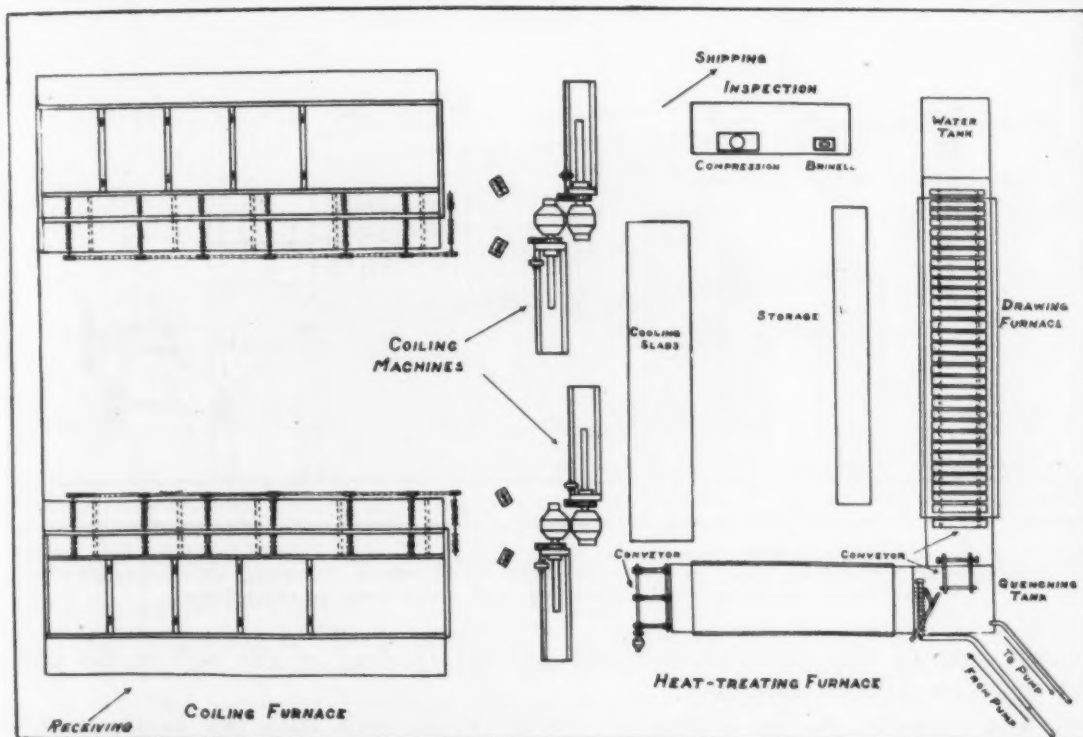


Fig. 1—Plan of a rapid production spring coiling and heat treating plant

sions are: 1 foot high, 5 feet wide, with a maximum length of 30 feet. The bottom of the furnace and the charging platform are sloped 1 foot in 10 feet. Standard heating units are mounted in the partition as well as in the side walls and bottom of heating chamber. The connections are made so that each chamber length is a separate electrical unit. The resistors in the movable partitions are automatically disconnected on raising the partition. The resistor grooves are open into the furnace chamber and in the bottom run at right angles to the longitudinal axis of the furnace. The surface of the refractory slabs for bottom resistors are grouted with finely pulverized porcelain and fireclay mixture to render it hard and resistant to abrasion, the fire clay serving as the binder. The charging platform is just wide enough to permit the charging of about 20 bars and its slope is a continuation of the furnace bottom. The charging end wall is about 3 inches short at the

bottom, providing an opening for entrance into the furnace chamber. Flexible asbestos aprons swinging toward the interior of the furnace form a seal insulating the heating compartment and giving access to it.

The charge passes through furnace by gravity and discharges at conveyor or side onto a series of rolls which feed the bar stock to either one of two coiling machines. The placement of the bars on the roller conveyor is controlled by a lowering rack at exit end of furnace. The rack is in turn controlled by a switch to occupy a position slightly above the rolls.

The two coiling machines are set against each other as shown in Fig. 1.

The furnace assures uniform heating of bars for coiling at a correct rate and attainment of the desired coiling temperature over the entire length of the bar.

The sloping bottom, charging platform and roller conveyor at discharge door are labor saving devices of decided value, the furnace operator being able

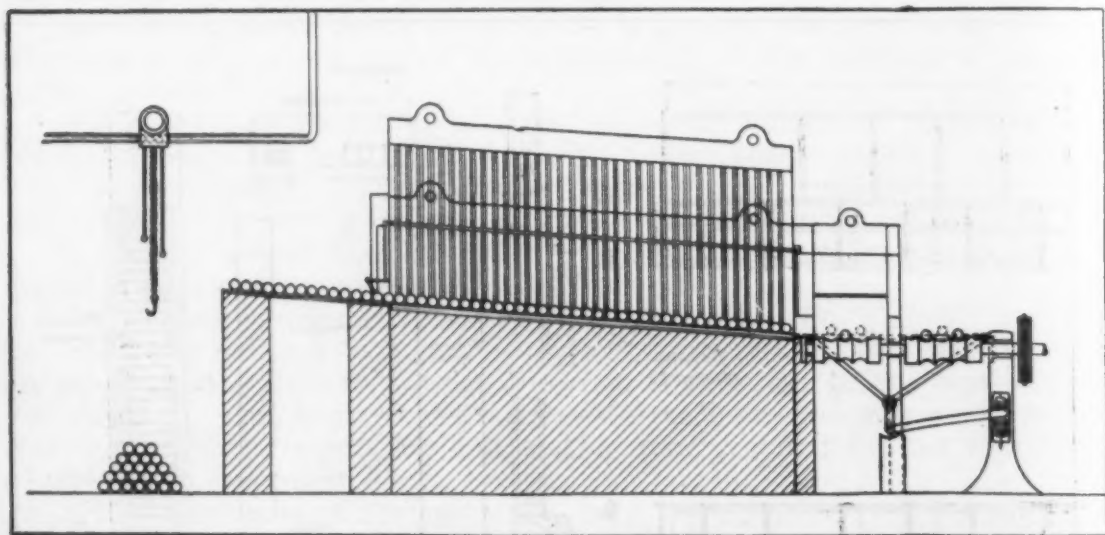


Fig. 2—Section through a resistor type electric furnace used in heating steel to be coiled into springs. This furnace is unique in that the heating chamber is adjustable in length, which permits of obtaining maximum heating economy with either long or short bars

to take care of the charging, heating, and the feeding of the rod to the coiling machine without difficulty.

The capacity of the furnace is about 60—1 inch bars per hour, or 480 bars per 8 hour day. The coiling of a spring takes nearly 2 minutes, consequently two coiling machines are fed continuously from this one furnace. By slight variations of procedure, different types and sizes of springs may be handled simultaneously.

The coiling machines need no special discussion. The direct motor drive is of such simplicity that its application and merits for this purpose are self-evident.

The choice of guides and mandrels is of utmost importance. The mandrel should be made to slightly taper about  $1/32$  inch per foot and preferably of a 0.30 per cent carbon,  $3\frac{1}{2}$  per cent to 5 per cent chrome steel.

The furnace is positioned so that its discharge end is practically at right angles with the head ends of the two coiling machines, No. 1 coiler feeding the bar over the mandrel for right handed springs and No. 2 under feeding it for right handed springs, the motors being set in batteries of two.



After coiling and marking, the springs are placed on cooling slabs, shown in Fig. 1, insulated with iron scale ( $\text{Fe}_3\text{O}_4$ ), lime or sand, and cooled to black heat of about 600 degrees Fahr. and then charged into heat treating furnace. However, immediate heat treatment can be permitted only when all variables influencing the uniformity of pitch, diameter of coils, and lengths are reduced to a minimum by a careful coiling method.

A resistance type of furnace is also employed to heat springs for the quenching operation. The dimensions of heating chamber are 1 foot 6 inches high, 4 feet wide, and 15 feet long. It has a sloping bottom of 1 foot in 15 feet, with a horizontal section about 5 feet long at discharge end. The sloping bottom insures continuous feed. A double row of about 60 springs of approximately  $5\frac{1}{2}$  inches diameter and up to 22 inches in length constitute a charge. The available time for heating springs in the furnace from 600 to 1500 degrees Fahr. is  $1\frac{1}{4}$  hours, giving an average rate of temperature

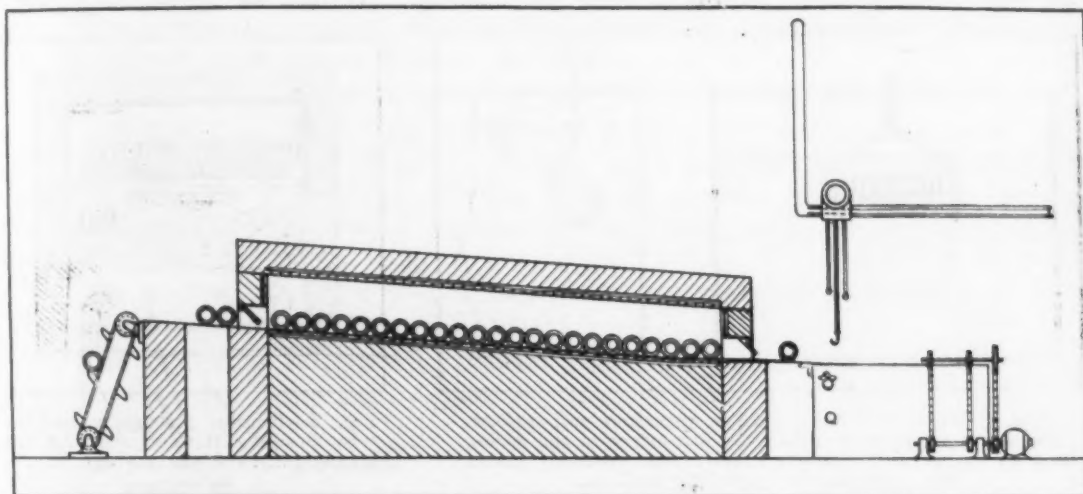


Fig. 3—Section through a resistance type electric heat treating furnace used in heating springs prior to quenching

increase of 12 degrees Fahr. per minute, this is in order to insure proper uniform grain refinement.

The charging is performed with a sprocket chain conveyor shown in Fig. 3, which deposits the spring upon the sloped charging platform where it is directed into the furnace by the furnace operator. No doors are provided for this furnace, the front and rear openings being insulated by flexible asbestos aprons. The ribbon type resistor units are open into the heating chamber. At the bottom they are inserted parallel to the longitudinal axis of furnace. The surface of the bottom is grouted for abrasive purposes with hard porcelain powder and fire clay mixture, similar to the bottom of coiling furnace.

The spring, when at the correct temperature of approximately 1500 degrees Fahr., is drawn into a perforated scoop shown in Fig. 4 for quenching. This scoop serves to maintain the symmetry of the spring and by means of the hanger construction, correctly places the spring in the quenching medium. The perforations are of such diameter and mesh that sufficient strength with least contact surface is obtained. The curvature of the scoop corresponds to the curvature of the coil.

#### Quenching Equipment

The quenching equipment consists of a steel tank 3 feet deep, 4 feet wide

and 6 feet long, filled with oil agitated or sprayed so as to insure uniform hardness of internal and external parts of the spring. Failure of helical springs usually starts from some internal point, approximately 45-60 degrees from the inner line. The examination of such fractures invariably revealed a decidedly soft steel at the origin of failure, caused by retardation of rate of cooling, resulting from the presence of a gas pocket in the oil.

The life of a spring subject to heavy service varies with the degree of uniformity of the proper hardness and toughness. It is obvious that a quenching system should produce springs having uniform and consistent properties and therefore a long life in service.

The oil tank has a capacity of 550 gallons. The circulation through the cooling system is at a rate of about 175 gallons per minute or the oil renews every 4 minutes. A spring having a weight of 50 pounds is quenched in this tank from 1500 to 200 degrees Fahr. in  $1\frac{1}{4}$  minutes, or at a rate of 20 degrees Fahr. per pound of steel per minute. When the spring has cooled

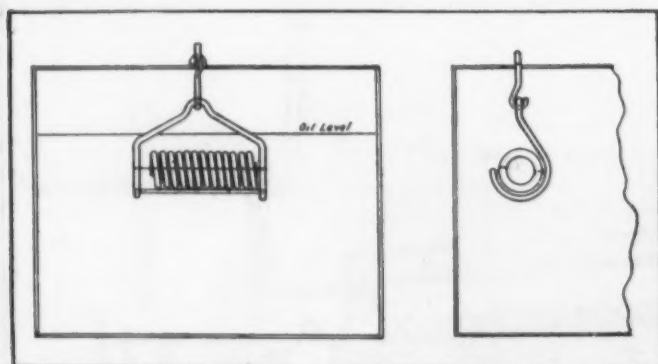


Fig. 4—Perforated scoop used in quenching coil springs. The scoop serves to maintain the symmetry of the spring and by means of the hanger construction, correctly places the spring in the quenching medium.

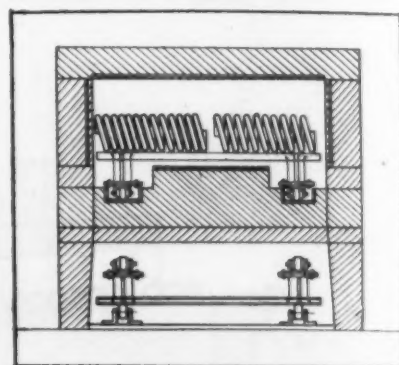


Fig. 5—Section through a resistor type drawing furnace showing the arrangement of the springs in the furnace.

to 200 degrees Fahr. it is placed upon the conveyor and delivered to the charging platform of the tempering or drawing furnace.

The scoop is fastened to the hook end of a small electric hoist so that positioning after receiving the hot spring and immersion in the oil is easily accomplished. The quenched spring should be drawn as soon as possible after completing the quenching operation.

#### *Drawing or Tempering Equipment*

The drawing equipment also utilizes the resistance type of furnace equipped with a continuous conveyor. The low operating temperatures of 800 to 900 degrees Fahr. permit the use of calorized sheet carrier materials for the shoes and gray iron, malleable iron and wrought iron for the other parts of the conveyor. The furnace is 1 foot, 6 inches high, 4 feet wide, and 25 feet long. The speed of the conveyor bottom is regulated to provide a speed of about 25 feet per hour. The spring is therefore drawn for one hour within the temperature range specified above, after which it is ejected and cooled in tepid water. It is then ready for inspection including Brinell hardness and compression tests. The electric features of the drawing furnace are similar to those of the others except that the stationary bottom is replaced by the conveyor. Fig. 5 illustrates the arrangement of springs in the drawing furnace.

#### **Summary**

It may be observed that the layout of this plant insures a maximum econ-

omy of labor and materials consistent with securing a high grade product constantly under technical control.

The features that merit particular consideration are:

1. Improved furnace design.

The three electric furnaces—the first for heating preliminary to coiling, the second for heating for quenching, the third for heating for drawing—are designed with automatic feed for maximum economy.

2. Appropriate design for securing proper temperature control with a minimum of power consumption.

3. Twin coiling machines with direct motor drive.

4. Special design of quenching mechanism to assure uniform hardness on all parts of spring.

5. Continuity of flow of material from raw stock to completed spring.

The output of a plant of this type would be approximately 450 springs of 50 pounds each on an 8 hour day basis.

The total floor space required is approximately 4000 square feet.

The output of the coiling machines is practically a fixed quantity for small and large springs. In order, therefore, to utilize the equipment effectively while manufacturing springs smaller than 50 pounds, an alternative arrangement, consisting of second coiling furnace and twin coiling machines is suggested and shown on Fig. 1.

The investment for a single unit plant and equipment exclusive of building should be approximately \$25,000.00.

The personnel required to operate the plant would consist of:

- 1—Foreman, who also assists the inspector.

- 1—Inspector.

- 1—Inspector's assistant.

- 6—Operatives.

- 1—Man in Receiving department.

- 1—Man in Shipping department.

Receiving and shipping men perform clerical duties also.

The principal items entering into the cost of spring manufacture are:

#### *I. Labor:*

- (a) Direct labor of the operatives, receiving and shipping men.

- (b) Salaries of inspectors.

- (c) Salary of clerk.

- (d) Indirect labor of the inspection, supervisory and clerical forces.

#### *II. Material:*

- (a) Raw stock for spring steel.

- (b) Fuel.

- (c) Quenching oil.

#### *III. Burden and Overhead:*

- (a) Depreciation of equipment.

- (b) Interest on investment.

- (c) Overhead on items I, II and III.

On the basis of present costs of labor and materials, the cost per pound of spring manufactured in the plant described wherein complete technical control of the product is secured, would approximate \$.03. The average 50 pound spring would cost therefore, about \$1.50.



THE ELECTRIC FURNACE AS IT EFFECTS OVER-ALL COST  
OF HEAT TREATED PARTS

By C. L. Ipsen

AS WE trace the development of the art of steel treating from remote times down to the present, we note that the advance has been associated with a progressive change from one type of heat source to another. Thus we pass from the early hand forge, burning wood or charcoal, successively through the coal and coke furnaces, the oil furnace and the gas furnace, until we come finally to the electric furnace. It is especially noteworthy that each change in the development has been to a fuel or heat source having a higher cost. While these progressive changes have not been universally adopted, it can not be doubted that they have been made on a sound economic basis, since there have been no backward tendencies.

The higher priced, improved heat source, has successfully withstood the competition of existing fuels, which indicates that there are other factors of greater importance in the heat treatment of steel than furnace operating costs, a fact which is not commonly recognized by the average furnace user. Most prominent among these other factors are:

1. Reduced cost of subsequent operations.
2. Reduction of the number of rejections.
3. Increased life of product with more satisfactory service.

In order to determine to what extent these factors will overcome higher furnace operating costs, an accurate cost analysis is necessary, which will show the influence of furnace operating costs on the cost of the finished product.

Table I has been prepared for this purpose, and shows actual ultimate costs of several familiar heat treated parts, together with the total cost of heat treating, as well as the cost of electricity used as a heat source. Attention is directed particularly to the last column, in which is shown the part that electricity plays in the ultimate cost. The electric power rate for all items is \$.015 per kilowatt hour.

The various dies, items 1 to 6, are heated in the furnace shown in Fig. 1. A similar furnace is used for preheating, and an electrically heated oil bath is used for drawing. These furnaces, and the oil tempering bath, are maintained at temperature constantly throughout the day, and the cost of the electricity thus used is apportioned among the dies treated over a certain period. If the furnaces could be operated at full capacity constantly, the cost of electricity would be from 10 to 20 per cent of the values given.

This furnace, shown in Fig. 1, has been run constantly for 25 months at a temperature of 1500 degrees Fahr. For the first 9 months of this period it was run 24 hours a day, 7 days a week. Since that time it has been run from 4 A.M. to 4 P.M., an automatic time clock being used to throw the power on in the morning and off in the afternoon.

During the 25 months of operation there has been no interruption of service, and the only expense incurred has been the replacement of a relay coil on the control panel, at a cost of less than one dollar. A metallic resistor heating element of the construction shown in Fig. 9 is used. No deterioration in this resistor is apparent after the 25 months continuous service. The only

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A paper presented at the Indianapolis Convention of the Society. The author, C. L. Ipsen, is designing engineer, Industrial Heating Department, General Electric Co., Schenectady, N. Y.

attendance necessary is occasional oiling of the automatic control instrument and putting in a roll of record paper, the controlling of the temperature and the throwing on and off of the power being automatic. This information is given to show that the electric cost, as indicated in Table I, is the only expense incurred. There is no continuous repair bill.

We have then, as the total cost of electricity in heat treating these dies, an amount equal to 0.3 of one per cent of the ultimate cost of the die. Subtracting from this the cost of other kinds of fuel, will give the amount that must be offset by these other factors such as reduction of rejects, etc. In the case of this die heating furnace, the cost of electricity is practically the same as the cost of oil. Extensive tests were run on similarly constructed oil and electric furnaces, to determine the policy of this company on future tool

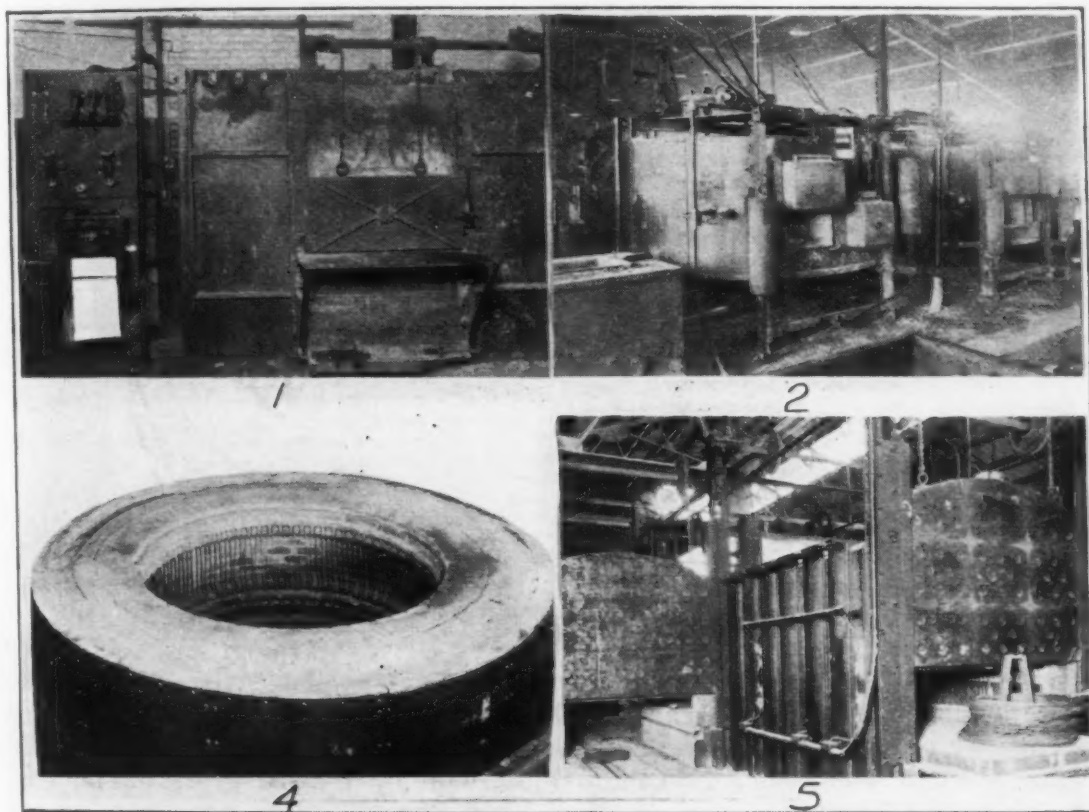


Fig. 1 Electric furnace similar to the one in which items 1 to 6 of Table I were heated.

Fig. 2 Electric furnace of the rotating annular ring hearth metallic resistor type.

Fig. 4 General construction of a gun tube and jacket heat treating furnace used extensively during the World War.

Fig. 5 Recuperative electric furnace used for annealing steel wire. The charge after being heated to the proper temperature is placed in the cooling chamber where it imparts its heat to the incoming cold charge.

treating furnace installations. The cost of operating the oil furnace was \$.23 per hour with oil at \$.13, and the electric furnace \$.10 per hour. With oil at its present level the costs are thus about equal.

However, in certain localities this would not be the case, and we must then look to these other factors to justify the use of electric furnaces. In the case of these dies the most prominent of these factors are the reduction of rejections, lower cost of subsequent operations, and longer life of dies. Unfortunately, accurate data are not available on these factors, but in the opinion of the foreman in charge of the work they amount to several

per cent, the reduction in rejections alone being over one per cent or three times the total cost of electricity.

Items 7 to 12 inclusive are at the present time treated in an oil furnace, the cost of electricity having been calculated on the basis of experience with electric furnaces handling similar work. Electric furnaces are contemplated for these parts, as a cost analysis indicates that the increased cost of electricity will be several times offset by the improvement in quality.

A furnace with a rotating annular ring hearth, shown in Fig. 2 is used for heating gears, item 13 of Table I. The cost of electricity for heating these gears is based on thirty days operation, 9510 gears weighing 39,107

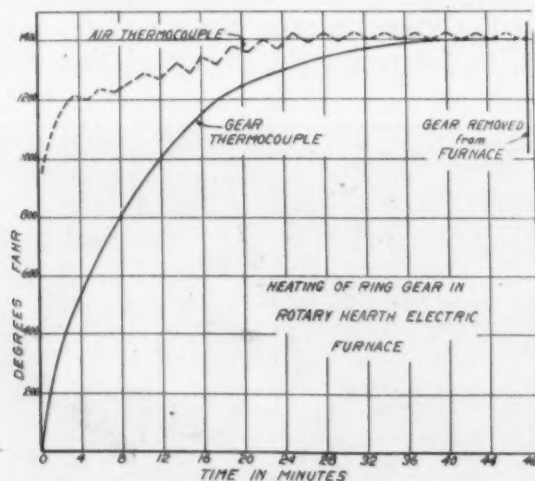


Fig. 3. Time-temperature curve of ring gears heat treated in rotary hearth electric furnace. The solid line shows the temperature of the gear with thermocouple in contact with it. The broken line shows the temperature of the furnace when a thermocouple was placed a few inches from the gear.

pounds being heated in that time. The cost of oil used in heating this same gear is approximately \$.005 or about 1/5 of the cost for electricity. To offset this increased cost of electricity we have the reduction of rejections and lower cost of subsequent operations.

While the reduction of rejected gears due to warping has been very greatly reduced, figures as to the number are not available; however, it has been possible to treat the gears in the electric furnace, so as to have an eccentricity of approximately half of the limits set for oil furnace practice, and limits which it was found difficult to meet with oil treated gears. The cost of subsequent operations was reduced approximately \$.05 per gear, or an amount equal to twice the total cost of electricity for heating.

The higher cost of the improved heat source, in every case cited, has thus been justified on the basis of the quality of the finished product, as it is reflected in the reduction of rejections, lower cost of subsequent operations, and longer life of product, any one of which, will, in most cases, many times offset the increased cost of the improved heat source.

The features of the electrically heated furnace of the metallic resistor type, which make possible this improvement in quality are:

1. Low temperature of heat source.
2. Accurate and reliable automatic temperature control.
3. Uniform and unvarying temperature distribution.
4. Absence of severe oxidizing and corroding action common to some fuel fired furnaces.

The large area of the heat source, permits it to operate at a temperature



only slightly higher than the temperature of the parts being treated, and renders overheating of any part impossible. In the fuel fired furnace except where a muffle is used, the heat source or flame is several hundred degrees hotter than the work. With these high temperatures of heat source, there is always danger of overheating portions of the charge, especially parts having thin sections. This overheating results in distortion and excessive scaling of the parts.

Automatic control of temperature insures constant conditions in the furnace, and makes possible the duplication of results from day to day. A

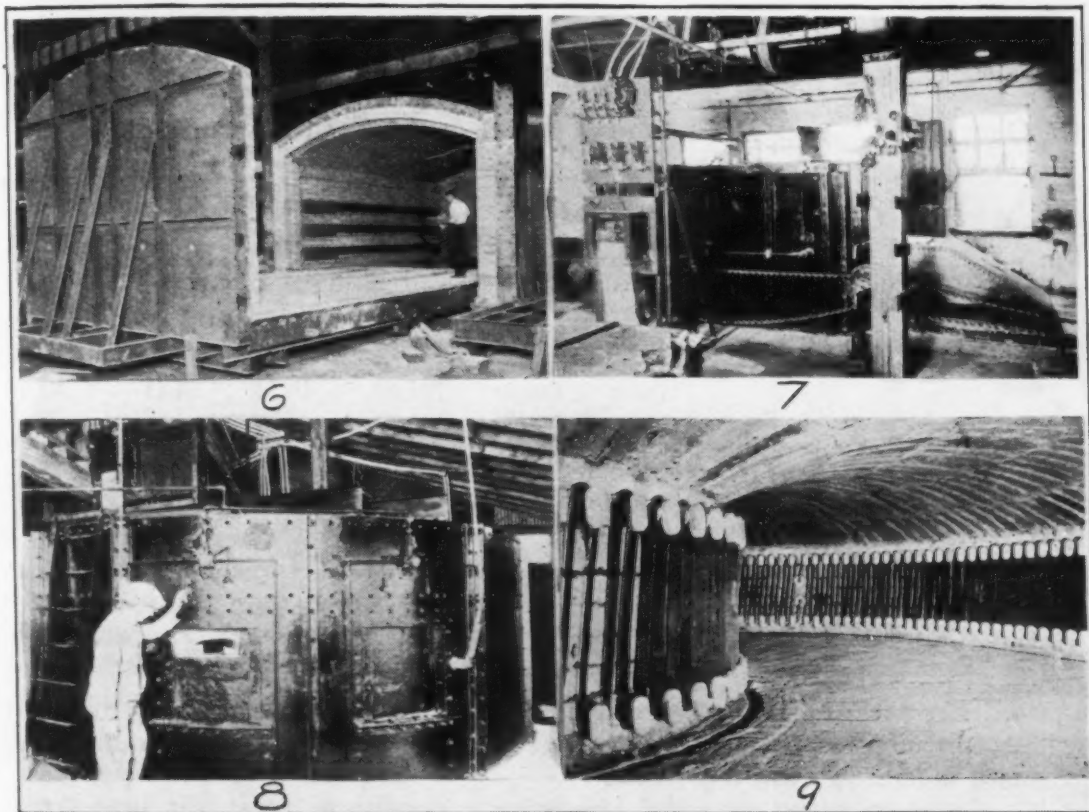


Fig. 6 Resistor type electric furnace used for annealing large iron castings. This furnace it will be noted is of the car bottom type.

Fig. 7 Resistor type electric furnace having a water sealed conveyor. This furnace is used for bright annealing nickel silver blanks.

Fig. 8 Exterior of a large rotating hearth furnace being used in an automobile factory for the heat treatment of cam shafts connecting rods, front and rear axles, steering knuckles, etc.

Fig. 9 Interior of the rotating hearth furnace shown in Fig. 8. The arrangement of the metallic resistors is clearly shown.

temperature control chart is plotted each day. Regular runs with such a furnace show a maximum temperature variation of about 5 degrees Fahr. plus or minus in the air of furnace. This is the variation of air temperature, and since the air changes temperature much more rapidly than the charge, it will be apparent how accurately the temperature of the charge is maintained.

Fig. 3 is the time-temperature curve of gears treated in a rotary furnace similar to Fig. 2. Sensitive thermocouples were attached to a test gear, which was placed in the furnace among the others in regular production. The "gear" thermocouple was embedded in the body of the gear itself, and the "air" couple was located a few inches above the gear. The curve is copied direct from the chart made by recording instruments. It will be observed how

accurately the temperature of the gear is held at 1400 degrees Fahr. up to the time it reaches the discharge door. It will also be observed that fairly wide changes of air temperature caused by throwing the power on and off, caused no appreciable change in the temperature of the gear.

This curve also illustrates another point; the uniform temperature that it is possible to obtain in a furnace of the metallic resistor type. In this furnace the windings are all on one circuit, and yet it is possible to maintain, by a proper distribution of the windings, a uniform temperature up to a point directly in front of the discharge door. The heating of a charge under these conditions insures uniform heating. In uniform heating, distortion and

Table I  
Over-All Cost in Producing Typical Heat Treated Components

Item	Part	Operation	Factory Cost	Cost of Electricity		
				Heat Treating	Heat Treating	Cost
1	Segment Combination Die	Harden & Draw	\$1380.00	\$13.50	\$4.16	.3
2	Combination Die	Harden & Draw	1138.00	12.00	3.70	.32
3	Round Blanking Die	Harden & Draw	638.00	5.03	1.50	.23
4	Segment Blanking Die	Harden & Draw	782.00	9.45	2.92	.37
5	Die	Harden & Draw	795.00	10.53	3.43	.43
6	Die	Harden & Draw	875.00	8.66	2.67	.3
7	Gear	Harden & Draw	234.00	13.00	3.70	1.5
8	Gear	Harden & Draw	263.00	15.00	4.44	1.7
9	Gear	Harden & Draw	338.00	21.00	6.25	1.8
10	Gear	Harden & Draw	391.00	26.00	7.60	1.9
11	Gear	Harden & Draw	455.00	30.00	9.06	2.0
12	Die block	Harden & Draw	110.00	1.75	.65	.6
13	Gear	Harden	5.00		.0286	.006
			(estimated)			

internal stresses are reduced to a minimum, and the quality of the heat treated part improved. This will manifest itself both in reduction in rejections and increased life of product.

In the electric furnace ideal atmospheric conditions exist for heat treatment, with the result that heat treated parts are practically free from pitting and scaling. This reduced scaling and pitting reduces the cost of subsequent operations in cleaning the dies and gears previously referred to.

Even in the face of the large savings that can be effected thru the use of the electric furnaces, as shown in the foregoing, their adoption has been delayed by difficulties in producing a dependable and reliable furnace. The use of early furnaces was fraught with all manner of difficulties. The frequent shut downs and costly repairs dampened the enthusiasm of the most ardent followers. It was only in recent years, under the stress of war time demands, that a type of furnace was evolved that could compete with the fuel fired furnaces on the basis of dependability.

The first furnaces of this type were built for heat treating gun tubes and jackets. Fig. 4 shows the general construction. This form of construction of heating units is extremely flexible in its application, and can be mounted in practically all types of furnaces used for the heat treatment of steel.

Data is at hand relative to a car bottom furnace used for annealing steel castings with 1500 pounds per charge. This furnace has been in operation

for 18 months. The cost of operation is approximately the same as for the oil fired furnace. The quality of the product shows decided improvement over the oil fired product.

Fig. 5 is a recuperative furnace used for annealing steel wire. The charge after being heated to the annealing temperature is placed in the cooling chamber where it imparts its heat to the incoming cold charge. Thirty eight tons of wire have been annealed in this furnace in one day of twenty four hours. The furnace has been in continuous operation one year.

The furnace shown in Fig. 6 is used for annealing large iron castings. A sixty ton charge is annealed at a temperature of 550 degrees Cent. with a temperature distribution of plus or minus 5 degrees Cent. throughout the furnace chamber.

Fig. 7 is a water sealed conveyor furnace for bright annealing nickel silver blanks. It has a capacity of approximately 1200 pounds per hour.

Figs. 8 and 9 are exterior and interior views of a large rotating hearth furnace installed in an automobile factory. The hearth is annular shaped 5 feet wide (5 feet inside diameter, 15 feet outside diameter.) During the day about 2700 pounds of cam shafts, connecting rods, front and rear axles, knuckles, gear blanks, etc. are put through per hour for hardening or annealing and the furnace is used for carbonizing at night.

Three years operation of a large number of furnaces of this construction have earned them the right to be considered in a class with the best of fuel fired furnaces, from the standpoint of dependability and for continuity of service.

The problem confronting anyone in the choice of steel treating furnaces is thus chiefly the problem of determining the effect of the various furnaces on the over-all cost of the heat treated part. A careful analysis along the lines outlined in this paper may in many cases reveal that furnace operating costs are of secondary importance. After three years of experience in the use of electric furnaces for steel treating in large scale production it is safe to predict that in the majority of cases where a high grade product is required, the lowest over-all costs will be obtained through the use of electric furnaces.



## WHAT IS STEEL

By John A. Mathews

THE officers of the New York chapter of the American Society for Steel Treating, I understand, have decided to cover in a fairly systematic way the metallurgy of steel in the various meetings this winter, rather than to depend upon papers of a miscellaneous nature such as have been heretofore presented. It seems to me that this should be a valuable and instructive course and I am convinced of the wisdom of the officers in outlining such a program, but I am not convinced that they made a wise choice in their first speaker.

However, if it is proposed to discuss metallurgy in a fairly comprehensive way, it is wise to begin with the fundamentals and lay a sound foundation upon which to build later in the winter.

In connection with the use of English, we have authorities who tell us from time to time what constitutes good usage, and what is the correct use of words. We have a committee on simplified spelling composed of distinguished scholars, who from time to time, publish a list stating what words we may misspell with impunity. We all recall words that a few years ago were considered as slang, or at least, as not quite right for dignified conversation, but which have now become adopted into the language and seem to have the sanction of good usage on the part of writers and speakers of note. I believe I recall one eminent professor who has passed upon the expression "it is me," but unfortunately at the moment I do not recall whether he said that this was good usage or not. The point I want to bring out however, is, that preciseness of thought will lead to preciseness of expression, and it will clarify our ideas and prevent misunderstandings, if when we talk about iron and steel, we all mean the same thing by the same words.

When I was a boy, I had a very thorough training in the Westminster shorter catechism. I never knew just why it was called the shorter catechism, for it consisted of over one hundred questions and answers, to a considerable extent, definitions. I never inquired what the longer one was like. However, I did know the shorter one forward and backward, and I recall the concise definition of sin. The difference between sin and steel is that our ideas on the former have remained fairly well fixed during the two hundred fifty and more years since these eminent theologians defined it, whereas our ideas in regard to steel have undergone radical changes during that period, as the processes of manufacturing it have changed.

Prior to 1740 practically all steel was made by the cementation process from wrought iron. In 1740 came the Huntsman process for the manufacture of crucible cast steel, and from that time to this, many others processes have been invented, many improvements have been made, and our ideas pertaining to this substance have undergone changes. But, before we discuss steel, a few words on iron are in order.

The word *iron* is used loosely by the general public, and sometimes by technically trained men to represent a great variety of materials differing widely from one another. First, iron means the chemical element *ferrum* represented by the symbol *Fe*. The pure chemist in speaking of iron would probably mean the chemical element. We also speak of iron meaning the wrought iron product, more or less fibrous in structure, and containing a considerable

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A paper presented before the New York chapter. The author, Dr. John A. Mathews, is President of the Crucible Steel Co. of America.

quantity of slag. It is sometimes produced directly from the ore, and sometimes from another variety of iron, namely, pig iron and cast iron. The word iron is sometimes loosely used in speaking of iron ore, as for instance, it might be said that there was a great deal of iron in the state of Michigan, or that the iron carried on the Great Lakes was 30 million tons per annum. In this usage no intelligent man would be misled but it would be clearly understood that the ore, the oxide of the iron, rather than the metallic iron was meant, but the distinction between wrought iron and cast iron is not always clearly made in conversation and writing, and sometimes one has to inquire as to what particular variety of iron is referred to. *Steel* itself, is as much a variety of iron as is pig iron and wrought iron. In fact, it is made from wrought iron by carbonizing and from pig iron by decarbonizing. Is it possible then to draft a precise definition defining exactly what steel is? What are the essential features which the material must possess?

In my library, I have a collection of metallurgical books dating from 1540 down to the present time. In examining many of them I fail to find any explicit definitions of *steel*. For instance, in an essay on "Metallick Words" by Sir John Pettus, published in 1683, we have a glossary of principal metallurgical terms of his day, but under *steel* I do not find a definition. All that he says is, "Now this and all other sorts of iron are by Pliny comprehended under the word *stricturae*, and he saith that the goodness of the steel ariseth from the goodness of the iron mine from which it comes with the assistance of waters and various quenchings of it in waters and oyls," to which he adds, "'Tis wonderful that man's blood should have such virtue in it as to be revenged on the iron blade that shed it, being once embrewed therein, it is given ever after to rust and canker." This quotation is of interest because it points to the very early knowledge of steel by the Latin writers and it shows that hardening in both water and oil was known at that early time; and in view of the fact that there was no chemical knowledge of refining and purification of the iron ores at that time, the merit of the products of such mines rested on the quality of the ore therein contained. This was true down to the very modern times, in fact, down to the invention of the basic process.

In the early colonial days of our own country, and extending down to the beginning of the last century, small plants were started to make tool steel. Usually they drew on the local ores and usually the plants were of short duration, because of the fact that the local ores did not produce iron of suitable quality for tools. The only way that the manufacturers could determine this at that time was by actual trial to discover whether ores were of high grade or not, as even chemical analysis was not used as a routine method in iron production of 50 years ago. The fine steel industry of France never made much progress until very recent years, and for this Reamur was largely responsible. He was the pioneer metallurgist in the early 1700's and in fact, was the pre-eminent man in this line in his time. He went on record to the effect that good steel could be produced from the local ores of France and the Government for many years would subsidize the steel industry which would undertake to produce their products from local ores. At the same time, England and Germany recognized that certain ores were much superior to others, and that the ores of Sweden were the best in the world. England, therefore, built up a great reputation for fine steel based upon the use of Swedish raw materials, as did also Germany, while the Austrian ore

posits in certain districts were of very high order and served as the basis for a substantial fine steel industry.

Therefore, from Pliny's time down to almost the beginning of our own generation, the chance selection of an ore determined whether or not a steel enterprise would be a success, and only after long experience, certain ores were demonstrated to be good, while others were not good. But the reason why they were not good was not thoroughly understood, because chemical analysis and other methods of investigation were not available to the early iron makers.

But to return to the matter of a definition. I have searched the works of many others from Sir John Pettus down to the present day, and I can find whole volumes written about iron and steel, but without an attempt anywhere in them to define what they are. By many, the capacity for hardening in water has been considered as the distinguishing characteristic of steel. By others, it is considered that the preparation of this form of iron by a melting process is essential to distinguish steel from the other forms of iron, the result of melting the raw materials being largely to free them from slag and inclusions which are characteristic of wrought iron. The third quality generally considered as necessary is that of malleability. This distinguishes steel from cast iron. It is my opinion that the two really essential characteristics are: First, manufacture by melting, second, the quality of malleability. It does not seem to me that the property of hardening should be considered as essential for the definition. There was a question discussed a few years ago as to whether the name *ingot iron* was the proper one to describe a well known American product. In my opinion this should be called *ingot steel*. It is extremely low in carbon and will not harden in the ordinary sense of the word by quenching in water. Nevertheless, it is manufactured by melting in the Open-Hearth furnace and results in a product which is malleable. It is free from slag and inclusions, and therefore, should not be called iron, thereby likening it to wrought iron which has not been produced by a melting process, which is not free from slag and inclusions, but which is of course, malleable. The matter of hardening is a question of degree and the degree of hardening increases directly with the carbon content. While a steel extremely low in carbon does not harden to a very material degree as measured by the scleroscope and Brinell test, nevertheless, such carbon as it possesses may be converted into the martensitic state by heating to a high temperature followed by quick cooling. It may therefore, be said to have been hardened, even though the physical hardness may not be materially increased, owing to the small amount of carbon. The operation however, will convert such carbon as it possesses into martensitic form which is the form that characterizes hardened steel, but the small amount of martensite is contaminated with so much free ferrite, which does not harden, that the final product will be physically soft.

In my opinion, steel as we now know it, the steel of commerce, whether made in Bessemer, open-hearth, crucible or electric furnaces is that form of iron which has been produced by melting to yield a finished product which is malleable. The question of carbon content and incidental presence of other elements is not vital to the definition. When we wish to refer to steel of bygone centuries prior to the invention of crucible cast steel we may still use the term steel, prefixed by cemented, blister, shear or double shear. These forms of steel did not disappear entirely by any means with the invention of the crucible process, but continue at a diminishing rate of production down to the present time. Their amount is so small, however, that when it is necessary



to refer to them the qualifying words should be used to indicate that the materials are essentially different from the steels of today.

We notice how successfully Sir John Pettus sidestepped any attempt to define steel in a book which was supposed to be a glossary and dictionary of technical terms of his time. However, the question of defining it in his time was much simpler than at present. The only material known as steel was cemented steel made from wrought iron that had been carbonized, and the finer grades were made by faggotting such carbonized wrought iron followed by welding and working down to smaller sizes giving the product known as shear steel, and this was sometimes re-faggotted, welded, and worked down a second time giving material known as double shear steel, and by this process of fagotting and welding, the alternate layers of high and low carbon steel had some opportunity to equalize by diffusion and were drawn out into thinner bands by the reworking, so that the finished product, in the case of the double shear steel was made up of relatively thin bands of high and low carbon steel which answered very well in its time for the production of tools of various kinds. It might be mentioned in passing that there had been produced in India from the very earliest times a fused product which was high in carbon made by melting down soft iron with carbonaceous material. This was the product known as Wootz Metal, but while its manufacture continued to a very small extent over many centuries of time yet the product was so difficult to forge and handle that it never made any impression on the industrial world, and was practically disregarded except as a curiosity, and the first steel that attracted attention and revolutionized the industry was the crucible cast steel of Huntsman in Sheffield about 1740. The Wootz Metal was melted in clay retorts and was allowed to cool in the furnace. It was, therefore, not cast steel. The principal difficulty which Huntsman had to contend with in perfecting his process, was in the producing of crucibles which would stand the high temperatures necessary for melting the wrought iron or converted bar iron. After he had succeeded in procuring the crucibles, there was little difficulty in the production of the first cast steel. Huntsman, however, in his first experiments, allowed the steel to cool in the crucibles which were later broken away and the resulting mass used as an ingot. Just when he began to pour the metal from the crucibles into a mold, I do not know.

Steel, then, as we know it today, began with Huntsman's invention, that is, the invention of cast steel made by a process of fusing, thereby eliminating slag and producing a product practically homogeneous in which the carbon and other elements were uniformly distributed through all portions of the product. The product was also malleable, and therefore, within the definition of steel based upon fusion and malleability. Steel prior to this time, was produced without fusion, by the process of carbonizing wrought iron.

We have used the word 'carbonize' several times and this brings up the question as to the use of the word *carbonize* versus *carburize*. I am inclined to think that some of our metallurgists have passed upon this use of words, and in general prefer the word *carburize* to indicate the process of adding carbon to low carbon iron or steel products. It seems to me that both words may be used to convey a definite distinction in regard to their usage. I am inclined to use the word *carburize* in connection with the process of adding carbon to the molten products of open-hearth, electric or Bessemer furnaces. Carbon is added to molten steel in the form of anthracite coal, charcoal, ferromanganese, etc. Sometimes the process is carried out in the furnaces and sometimes in the ladles, and this process it seems to me, might be covered by

the word *carburize*, while the process of adding carbon to solid steel as in the case-hardening operations, I am disposed to call *carbonizing*. Therefore, the old process of making a cemented steel would be considered a carbonizing process in which the bars of wrought iron were packed in charcoal and subjected to heat in furnaces looking more or less like pottery kilns for a period of 7 to 12 days. The same word would apply to the modern practice of case-hardening small finished parts, as gears, in which the finished parts are packed in various mixtures (with which the market is flooded) followed by heating in closed boxes, by means of which operation the carbon passes into the surface of the steel. The principal factors by which the case-hardening process is controlled, are time and temperature, and the raw material used in imparting the carbon. By the proper control of these elements we regulate the depth of case and maximum carbon content in the most highly carbonized zone, and to some extent we regulate the gradation of carbon from the outer high carbon zone to the inner soft carbon zone, and also to a certain degree, determine whether there shall be a sudden or gradual change from the hard to the soft parts.

It has been recognized for nearly 150 years that carbon is the element which confers on iron its wide variety of properties. When in definitions of steel, carbon is included as an essential, it is generally stated that the carbon content may vary from 0.10 to 2.00 or 2.25 per cent. The ordinary steel of commerce is well within these ranges and seldom exceeds in practice 1.50 per cent in the case of certain tool steels. The true upper limit, however, is the limit of forgeability, and this depends largely upon the skill of the one doing the forging. Plain carbon steels containing as high as 2.50 per cent carbon can be forged with difficulty, and many of the wire drawing dies or Wortle plates as they are sometimes called, contain over 2.00 per cent carbon, and I suppose that the theory of this use lies in the fact that the excess carbon exists in the form of cementite which is extremely hard, while the matrix is much softer pearlite, and presumably the cementite particles act to resist the abrasive action of the wire during the process of drawing. The principal difficulty in forging the extremely high carbon steels arises from the tendency of the excess cementite to break down into ferrite plus free graphitic carbon. Certain elements tend to keep the carbon in combination and certain other elements tend to precipitate the free carbon in high carbon steels. Manganese and chromium are the principal elements which tend to keep it in combination, while silicon and nickel tend to precipitate free carbon. When it comes to a matter of carbonizing steel the same elements act the same way. High chromium and manganese seem to facilitate the absorption of carbon while silicon and nickel tend to retard the absorption of carbon.

In addition to the iron and carbon present in all commercial steels, there are four other elements ordinarily present whose effects must be considered. They are manganese, phosphorus, sulphur and silicon. These are often considered as impurities since it is almost impossible to make steel free from them. The first two elements, however, especially manganese, must be considered essential and beneficial, while phosphorus and sulphur are nearly always undesirable. Copper and arsenic are usually present in minute quantities and in amounts ordinarily present, their effects are negligible. Aluminum is not normally present for the reason that it cannot be eliminated, but because it is added to the steel during casting and traces of it may be found in the finished product. Ordinary steel, then, by whatever process made, may contain carbon and manganese from 0.10 to 1.50 per cent; silicon from trace to 0.25

per cent; phosphorus and sulphur from below 0.01 to 0.10 per cent; with copper, aluminum and arsenic in negligible quantities. Steel usually contains hydrogen, oxygen, nitrogen, and cyanides in minute quantities, which are not readily determined. Nevertheless, we must assume that each and all of these elements exert some influence in regard to the final quality of the steel. We have much to learn as to just how they act and as to what this influence is, particularly in regard to tool steel. It so often happens that two samples of steel, of practically identical analyses as far as ordinary elements are determined, give such different service that we are forced to the conclusion that there are other factors than those which our present methods of investigation deal with, which control ultimate quality. This mysterious something called quality, is frequently called by the British, *body*. Just what body is, I have never seen defined. Probably it goes back to the original statement referred to in the early part of this paper by Pliny; i. e., to the mine itself, in which the ore is produced. Steels coming within the limits of analysis just mentioned serve an enormous number of purposes and in a certain sense that particular analysis which yields a steel suitable for rails, springs, knives, drills, and gun barrels, may be considered a special steel. Such is not the commonly accepted significance of the term special or alloy steel, although as has been seen, all steel is an alloy. By common consent, we consider it almost as though it were a chemical element, as though it were a simple substance instead of an alloy of from two to ten constituents. When we materially exceed the limits of the analysis already given, or when we add to ordinary steel other elements not normally present, for example; nickel, chromium, vanadium, or molybdenum either by intention or chance, the product is an alloy or special steel. When one of the normal constituents, silicon or manganese is greatly increased in quantity, it becomes difficult to decide arbitrarily the percentage at which we pass from regular carbon steel to an alloy steel. Abnormally raising the ordinary constituents, so alter the properties of the resulting alloy that many useful purposes are served and results not otherwise obtainable are secured. We thus see why the term alloy steel has acquired a special significance meaning any steel to which in addition to carbon and iron and impurities common to all steel, other metals or metalloids have been purposely added to change or improve its natural properties. Chemically pure iron may properly be classed among the rare metals.

Not only is steel a very complex material, but its complexity is further increased by the allotropic character of the element iron and by the fact that carbon may exist in several different chemical combinations, while the same is probably true of sulphur and phosphorus. In cooling pure iron from the molten condition, we find its freezing point at about 1500 degrees Cent. All of its alloys with carbon up to 4.3 per cent melt at decreasing temperatures down to 1130 degrees Cent. Below the initial solidifying of pure iron, there are two other temperatures at which cooling momentarily stops. These temperatures are 895 degrees Cent. designated as  $Ar_3$ , and at 765 degrees Cent. designated as  $Ar_2$ . When carbon is present, a third very marked arresting of cooling occurs at 690 degrees Cent., known as  $Ar_1$ , the ordinary recalescence point.

It is believed by many that the molecular transformation occurring at  $Ar_2$  and  $Ar_3$  indicated allotropic changes in the iron itself. At temperatures above  $Ar_3$  we recognize the gamma-iron of Osmond, nonmagnetic and solvent for both elemental carbon and carbide. Between  $Ar_3$  and  $Ar_2$  points, iron exists in the condition known as beta-iron, also nonmagnetic but not a solvent



for free or combined carbon. Below  $A_{r_2}$  iron exists in its magnetic condition known as alpha-iron in which iron carbide is not dissolved, or only slightly.

There are many who do not accept the allotropic theory, but whatever significance these critical points may have, all concede that they do occur and that at certain critical temperatures the character of the iron undergoes profound changes. Those who do not admit the allotropy of iron neither dispute the allotropy of carbon nor its occurrence in iron in at least two conditions: First, as free graphite; second, as combined iron carbide, and it is generally supposed that this combined carbon may exist in steel as either isolated particles or in a dissolved state.

In general, it may be said that the influence of other elements upon iron-carbon alloy is:

1. To change the temperature of the occurrence of the critical points.
2. To modify the condition in which the carbon occurs.
3. To remove occluded gaseous impurities.
4. To combine chemically with the iron or carbon, or both.
5. Either combined or free to form iso-morphous solutions with the iron or to separate into distinct microscopic particles.

In thus deporting themselves these elements are found to improve or injure the steel, to make it harder or stronger, ductile or brittle, a better magnet or a better tool. The effect of these additions have been the subject of long and careful study, but the exact manner in which the added elements influence the iron carbon system so as to produce new and useful properties in steel is not yet perfectly understood.

Notwithstanding its complexity, steel and its alloys follow in many cases the general laws of physical chemistry which have been found to hold good for simpler and purer alloys, these laws being the laws of solution. Roberts-Austen and Spring found that one metal diffuses into another like salt into water. In general, solubility increases with the temperature. Metals and alloys will flow under pressure. Alloys may or may not react when brought into intimate association by fusion or pressure. Molecular mobility increases with the temperature. Upon cooling of molten alloys, phenomena suggestive of freezing salt solutions are observed. The depression of the freezing point of a metal when another is added to it follows the laws of Coppey and Raoult for dilute solutions, and generally the phase rule of Gibbs applies quite as well to the explanation of conditions of equilibrium in alloys as to similar problems in regard to liquid solutions.

It has been found as a result of the work of a number of investigators that the electrical conductivity of iron, as well as other alloys, is a function of the atomic weight of the added element so long as it dissolves in the principal metal to form a true solid solution.

It has been intimated, iron has been known from the earliest days of civilization. The art of carbonizing and hardening it probably antedates the Christian era. Cast iron and foundry practice dated from about 1400, and within a few years the crucible melting process will round out its second century. Notwithstanding this, all of us, especially the younger men who are just getting their first practical acquaintance with the handling of steel, are apt to overlook the fact that the present steel era is of very recent date: i. e., the steel for ordinary structural purposes, for rails, for ships, and for immense forgings for ordnance, machine construction and other purposes. This development has all come about within our own generation. We may almost say

that the age of steel in the United States began with the development of the basic open-hearth process about 1888. Bessemer steel had been produced much earlier while blast furnaces and foundries had been in existence in the country from the early colonial days, and in fact at one time iron was exported from this country to England, and its production in this country was stimulated by England. The production of various forms of iron in the early days was largely based upon the rule of thumb method, experience and knowledge passed on from father to son. Chemical methods were seldom applied, and in fact, the suggested introduction of such methods met with strong opposition on the part of the so-called practical steel makers. The laboratory chemist was not welcome, and has only been considered a necessary part of an iron or steel works for the last 40 or 50 years. The microscope and pyrometer were of much more recent adoption, and each in its turn met with opposition from the steel makers, and its benefits were scoffed at by the old time steel men. With the adoption of all of these additions which we have today, we must recognize that the making of steel is not an exact science. It is rather an art, to which scientific methods may be applied, but in its fundamental operations it still remains a handcraft industry, aided and guided by scientific control methods. Our young metallurgists are apt to become impatient because the steel cannot always do the impossible, and because the steel makers cannot manufacture their product 100 per cent perfect. This is the ideal for which conscientious manufacturers strive but which can never be perfectly attained.

To further illustrate the extent of recent progress, let me recall to your minds the state of the art and kindred arts just 100 years ago. Peter Barlow, a professor in England, published an essay on "Strength of Timbers and Other Materials." This seems to have been the beginning of the study of physical properties of engineering materials. His experiments included the study of iron and its properties with reference to design of bridges. The first American sheet rolling mills were built in 1818. Mill shafting was introduced in a mill in Manchester, by William Fairbairn, the shafting all being turned by foot lathes which permitted of higher factory speeds; size of shafts and pulleys were reduced. This brought about a revolution in power transmission as the shaftings prior to this time were made square, often of timbers, and fly and gear wheels were secured in place with wooden wedges. The first coke pig iron was produced in America in 1819 although it had been produced much earlier in England, and the first attempts in America with the use of raw bituminous coal in a blast furnace were made in the same year. The daily production of the Krupp Works at Essen was about 400 pounds of crucible steel. In 1820, the production of pig iron in America was about 20,000 tons.

A matter of very great interest to metallurgists is that in 1820, or just a century ago, alloys of iron and chromium were prepared by Derthier, and alloys of iron and nickel, chromium and some other rare metals were prepared by Michael Faraday. So far as we know, this is the beginning of alloy steels. Nevertheless, the commercial production of them did not begin until much later. So far as I have been able to learn, the production of Mushet air-hardening tool steel furnished the first instance of alloy steel used in the industry. This was about 65 years ago. In 1820, also, the first wrought-iron rail rolling mill was started in England and the manufacture of rolled boiler plates seems to have been started at about this time by Dr. Charles Lukens in the Brandywine Rolling Mill, and this industry, as you know, is still in existence under the name of the Lukens Iron & Steel Company. These plates

were rolled charcoal iron blooms. Peter Barlow made the first experimental investigation in regard to the phenomena of induced magnetism and perfected methods of adjusting ships' compasses by fixing small iron plates in position to compensate for various magnetic disturbances. It is interesting to note that experiments made by Faraday on alloy steels already referred to, were made for the purpose of,—first, making better cutting tools, and second, securing material that would be superior for reflectors, and while Faraday employed chromium in his experiments, it is interesting to note that we had to wait almost a century for the perfection of stainless steel which is a chromium alloy, and which may be used for the manufacture of metallic reflectors, which will not tarnish. Oersted, a Danish scientist, discovered electro-magnetism. Seebeck, a German physicist, discovered thermo-electricity and that current produced by heating two metals in contact increased with the temperature. This principle, however, was not applied to pyrometry until 1886. Faraday, also, pointed out the difference between annealed steel and hardened steel, showing that the hard steel dissolved completely in hydrochloric acid, while the annealed steel leaves a residue which he called carburet of iron. Barlow was continuing his work in induced magnetism and studied the effects of varying temperatures on the magnetic power of iron, and finally we might mention that the Rensselaer Polytechnic Institute was founded in 1824 to give instruction in "the application of science to the common purposes of life." It is the oldest engineering school except West Point in any English speaking country. These events of a century ago will help to impress upon your minds the remarkable progress that has been made in science, particularly as pertaining to iron and steel within that period, but its greatest advancements have been made within the present generation since steel became a tonnage commodity of such vital importance to the industrial life of every civilized nation.

In the field of iron and steel production, research has yielded most valuable results, and these progressive manufacturers who have recognized its importance, have profited much thereby. It should not be overlooked that the purpose of research in industry, like every other department in industry, is to increase profits. Manufacturing concerns exist for the making of profits and legitimate manufacturing profits in any company are the rewards that the public pays for service rendered or risk taken. The desire for profits is the impelling motive that leads manufacturers to take risks and build up industries that give employment to others. The research department of a steel company may function in many ways to contribute its part to the general success. Its first efforts should be to improve the product. Success in this direction leads to a greater demand, large output, greater ability to meet competition, and ability to command higher prices for the product. The research department should direct its efforts toward lowering costs:

1. By finding cheaper but satisfactory raw materials.
2. By improving old processes and developing new processes to increase the yield or decrease labor, or both.
3. By developing new products and finding uses for by-products.
4. By finding new uses for existing products.
5. By improving operating conditions in the plant not directly connected with the product itself, such as effecting savings in water, fuel, lubrication and electricity, and by improving the working cycles, material movements, and power conditions.

All of these results in public good and bring their reward because they lead to better goods, and the better supplying of public needs.



If it is commendable to make two blades of grass grow where one grew before, how much more worth while is it, to make one pound of steel go where two went before, by improving the quality and treatment, and adopting a metal particularly suited to requirements. Here we have real conservation in raw materials. The higher grades of ore are not believed to be inexhaustible and in making one pound we not only use one half as much ore but also one half as much fuel and refractory material as in making two pounds. Furthermore, if the steel becomes a moving part of a machine, automobile, or airplane, there will be a perpetual saving in motive power during the life of the machine. Sometimes it does not lead so much to conservation as to extension of use, for when such results are achieved more machines, automobiles and airplanes will be built and the maker of the steel will find a wider market.

Research in the steel industry has made possible the automobile and airplane, but we have been inclined to put it the other way, i.e., that the demands of the automobile and airplane produced the advancement of steel. It should be remembered however, that nickel, chromium and chrome-nickel steels all antedate these modern inventions. Dr. W. R. Whitney has well said, "Necessity is not the mother of invention; knowledge and experience are its parents." This is clearly seen in the case of many industrial discoveries. High speed cutting tools were not a necessity which preceded, but an application which followed, the discovery of the properties of tungsten-chromium-iron alloys; so too, the use of titanium in arc lamps, and of vanadium in steel were sequels to the industrial preparation of these metals and not discoveries which came by sheer force of "necessity."

Steel men,—always modest,—have been too modest in claiming their part in the wonderful developments in machine construction due to their efforts in producing steels that permitted of uses which formerly would not have been possible. The Ford car would have cost several times as much as it now does and the Ford plant would have been many times as large as it now is for the same production had it not been for Taylor & White's investigations on "The Art of Cutting Metals," and they probably could not be produced at all in their present design had only plain carbon steels been available.

Metallurgy is defined as the art of extracting metals from their ores, and strictly in accordance with the definition, there are relatively few metallurgists. Most of those who call themselves such, are principally interested in the metal after it had been extracted from the ore. The German term siderology, the science of iron, is deserving of wider adoption. Most so-called metallurgists might be more appropriately called siderologists, but one, who like myself, has graduated from the laboratory into executive duties, might then be called a "siderologist." After all, the contemplative side of science is important and while of routine testing we have done a great deal, we have been too busy to analyze results and draw conclusions and search hidden facts and relationships. Possibly this is to be expected in a relatively new country with abundant raw material and an almost limitless domestic market for its manufactured products. In a new country like ours, we cannot expect the ripe scholarship of England and France. Many of the fundamental laws of science were discovered while we were in our colonial days, and development of a new nation is not compatible with the development of leisurely investigations. Research men, like poets, are born, not made. You can teach research methods, but you cannot provide a research mind. We have difficulty in finding men of the typical research make-up. In my experience, such men have

oftener been found among men of chemical and physical training than among men of engineering training. The great achievements of science and research in the past were not the work of committees, but of individuals. Newton, Davy, and Faraday, by reason of their innate ability and personal qualifications made their great contributions to science, and the greatest advances in basic science have been made in times of peace, and not in times of war. Militarism is fatal to the best scholarship that promotes public welfare and the advancement of civilization.

The writer outlined a program in which a research department may participate to promote the general interests of its industry. Not much exception could be taken to that plan by any board of directors or executives. But, how far shall we extend research into the field of so-called pure science in a money making institution? Here is where a difference of opinion is quite likely to be seen. In my experience, the pure science of today is the applied science tomorrow, and I have been impressed many times with the fact that discoveries of supposedly only theoretical value soon come to be applied to the practical affairs of manufacture. It is not my judgment that the pure science of the steel industry should be left wholly to the college laboratory or the Bureau of Standards, nor do I believe that the practical problems of the industry should be turned over to such institutions. The industry should assume all of its practical problems and most of its theoretical ones.

Research methods in the steel industry have been much extended during recent years, indeed, the general adoption of routine chemical analysis, physical testing, the microscope and pyrometer are all within the memory of men still active in the industry. Fatigue testing, shock and repetitive impact testing, dilatation, conductivity, and magnetic analysis as research methods in quite general use are developments of this century, and we may almost say, of the present decade. No one of these tests tells us all we would like to know about steel. They are mutually supplementary and the more we have of them the better. And with the use of all of them, in the case of steel that fails in service, it is sometimes very difficult to answer the question "Why did it fail?" From the steel makers point of view, in case of failure, the question to which an answer is most necessary is, at what stage of the operation of manufacture, or subsequent treatment, was the damage done? Was it the raw material, the melting or pouring, the blooming or cogging, the rolling or forging, or annealing? Was the steel 100 per cent perfect when it left the works? Was the damage done by the user?

Great strides have been made in investigation and research and many new methods of testing are at hand, but the field is not yet fully covered, and in answer to the question just propounded, we frequently have to answer, "I don't know."

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THE TOUGHNESS OF HIGH SPEED STEELS AS AFFECTED  
BY THEIR HEAT TREATMENT

By Marcus A. Grossmann

THE present paper offers the results of some measurements of toughness on hardened high speed steels, of two fairly common analyses. The steels were of an 18 per cent and a 13 per cent tungsten type. They were hardened at temperatures ranging from 1700 degrees Fahr. to 2250 degrees Fahr. and were tested as quenched and after drawing at various temperatures up to 1100 degrees Fahr. The toughness was measured in an impact machine of the Charpy type, on test pieces that conformed rather closely to the dimensions of the standard Charpy bar, but were unnotched. The toughness, as expressed in foot-pounds absorbed in breaking the test piece showed variation with the heat treatment. The character of this variation was about the same in the two steels, although the absolute values were different in the two cases. As the quenching temperature was increased, the toughness decreased at first rapidly, then more gradually. As the drawing temperature was increased, the toughness increased to a maximum at about 900 degrees Fahr., and then decreased somewhat at 1100 degrees Fahr.

Steel 13, with about 13 per cent tungsten, was made in a crucible heat, the ladle analysis of which is shown below while Steel 18, with about 18 per cent tungsten, was taken from a stock of approximately the following compositions as shown.

	Steel No. 13	Steel No. 18
Tungsten.....	12.97 per cent	18.00 per cent
Carbon.....	0.85 "	0.65 "
Manganese.....	0.25 "	0.25 "
Phosphorus.....	0.025 "	0.03 "
Sulphur.....	0.036 "	0.03 "
Silicon.....	0.08 "	0.25 "
Chromium.....	2.81 "	4.00 "
Vanadium.....	0.20 "	1.00 "

The steel was hammer-cogged from a 5 inch ingot to a  $1\frac{3}{4}$  inch square billet and rolled to  $\frac{3}{8}$  inch square finished bars.

The test pieces were cut from annealed bars by means of a carbondum high speed cutting-off wheel, they were ground to length, and were then heat treated as follows: After a preliminary warming to about 250 degrees Fahr., the pieces were heated for about 10 to 15 minutes in a preheating furnace at about 1550 degrees Fahr., then transferred to the high temperature furnace where they were held only until they had reached the temperature of the furnace (about 3 minutes for the lowest temperatures, 50 seconds to 1 minute for the highest). They were then quenched in quenching oil. Those to be drawn at 350 degrees Fahr. were drawn in oil; the drawings at the higher temperature were carried out in a bath of molten potassium-sodium nitrate.

Steel 18 was hardened at 1710, 1880, 2020, 2110 and 2230 degrees Fahr., the temperatures varying plus and minus 15 degrees Fahr. in the course of the heat treatments. For each hardening temperature one series of

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steels was left as quenched, and one series drawn at each of the following temperatures: 350, 640, 880 and 1100 degrees Fahr, varying plus and minus 5 degrees Fahr.

Steel 13 was heat treated in a manner exactly similar to that of steel 18. The quenching temperatures were 1725, 1850, 2000, 2100 and 2230 degrees Fahr. The drawing temperatures were 340, 660, 900 and 1100 degrees Fahr., with about the same degree of constancy as in the previous case.

The test pieces were not notched. The dimensions conformed rather closely to the standard Charpy bar. With a view to using a size more readily available commercially than is the 10 millimeter square cross section, it was decided to use  $\frac{3}{8}$  inch square bars throughout these tests. This is of course 0.019 inch smaller than the 10 millimeter size. The test piece was made the standard 55 millimeter length (2.17 inches), and the testing machine was the standard 40 millimeter between supports (1.57 inches). The pieces were heat treated without previous machining.

The pieces were tested in an impact machine of the Charpy type, designed and calculated by the present author to conform rather closely to the Charpy machine. The constants of the machine are as follows:

Total weight of striking arm.....	19.7 pounds
Distance from axis of rotation to center of percussion.....	3.75 feet
Distance from axis of rotation to center of gravity.....	3.22 feet
Capacity of machine as installed.....	about 80 foot pounds

After the test pieces were heat treated, they were ground smooth on two opposite sides and placed in the testing machine so that a ground surface was in contact with the vertical supporting edges, and the other ground surface presented to the striking edge.

The results obtained with steel 18 are given in Table I, which gives in each case the average of all the tests for that particular heat treatment. The number in parentheses indicates the number of tests from which the average was calculated. The average is a direct numerical average and is not a weighted mean. These impact values (energy absorbed in breaking) were very far from being uniform for a particular heat treatment, and while in general the average of 5 or 6 tests would be fairly constant, a single reading was apt to be very misleading. The following series, quenched at 2230 degrees Fahr., with no draw, is a good example of the maximum uniformity obtainable. On the other hand the series, quenched at 2230 degrees Fahr. and drawn at 880 degrees Fahr., shows the variation liable to occur:

Foot Pounds	Foot Pounds
2.6	4.0
4.8	11.8
5.2	9.0
4.8	4.1
4.0	
4.6	
6.9	
Average 4.7	Average 7.2

It is believed that very close control of the rate of heating will lead to much more concordant results. The effect of the rate of heating is still under investigation and cannot yet be reported on.

In Fig. 1, the foot pounds are plotted against quenching temperatures, each curve representing a particular drawing temperature. The

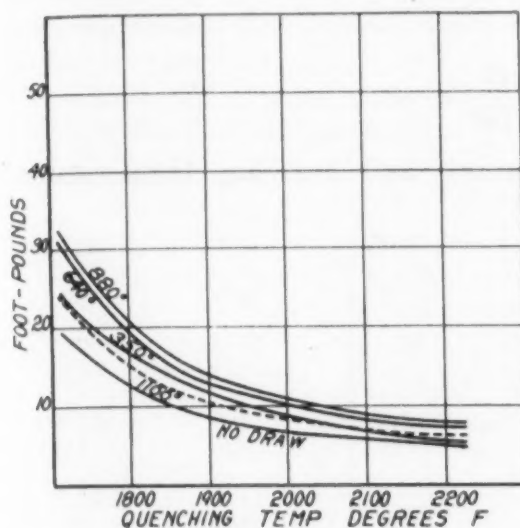


Fig. 1—Impact Values versus Quenching Temperatures 18 per cent Tungsten Steel.

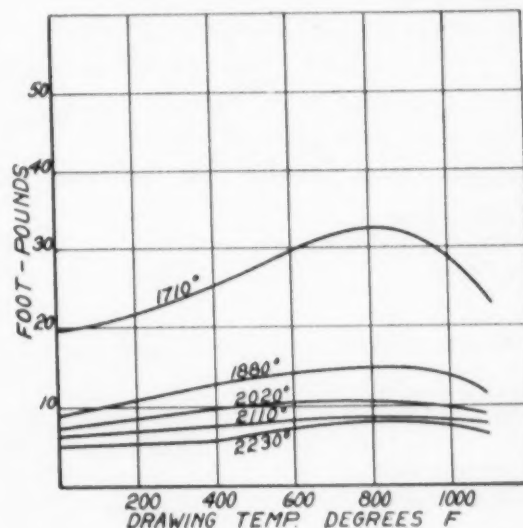


Fig. 2—Impact Values versus Drawing Temperatures 18 per cent Tungsten Steel.

curves are not drawn exactly through all the points given in Table I, as there are a few points off the curves which would confuse their general appearance. All the data available were considered in drawing up the curves shown, and it is believed that they show fairly accurately

Table I  
Steel XVIII

Impact test results for various hardening and drawing temperatures

Hardened at					
Degrees Fahr.	1710	1880	2000	2110	2230
No draw	19.9	7.1	7.5	6.2	4.8
	(6)	(5)	(6)	(16)	(19)
Drawn at 350					
Degrees Fahr.	24.3	13.3	5.8	5.8	5.2
	(3)	(4)	(9)	(13)	(16)
Drawn at 640					
Degrees Fahr.	31.1	13.7	10.9	4.0	7.6
	(5)	(4)	(4)	(4)	(4)
Drawn at 880					
Degrees Fahr.	16.5	15.0	10.1	8.2	8.0
	(4)	(4)	(4)	(14)	(14)
Drawn at 1100					
Degrees Fahr.	24.4	11.2	4.2	6.7	6.5
	(4)	(4)	(6)	(9)	(12)

the average results that may be expected from the heat treatments shown. This method of drawing up the curves was followed throughout. It will be seen that as the quenching temperature was increased, the

toughness decreased fairly rapidly at first, especially with low drawing temperatures. As the quenching temperature was increased still further, the toughness decreased less rapidly.

In Fig. 2 the foot pounds are plotted against drawing temperatures, each curve representing a particular quenching temperature. It will be seen that for each quenching temperature, the toughness increased as

Table II  
Steel XIII

Impact test results for various hardening and drawing temperatures\*

Hardened at Degrees Fahr.	1725	1850	2000	2100	2230
No draw	35.7 (6)	8.4 (5)	10.9 (8)	9.6 (10)	11.2 (8)
Drawn at 340 Degrees Fahr.	47.0 (6)	18.6 (5)	10.1 (7)	15.6 (12)	9.3 (8)
Drawn at 660 Degrees Fahr.	51.5 (6)	27.8 (5)	13.2 (5)	7.9 (5)	12.8 (5)
Drawn at 900 Degrees Fahr.	59.9 (6)	33.4 (4)	18.7 (8)	14.0 (10)	11.9 (8)
Drawn at 1100 Degrees Fahr.	56.5 (6)	18.0 (5)	8.6 (5)	9.4 (5)	7.1 (6)

the drawing temperature was increased, up to temperatures of about 900 degrees Fahr. At 1100 degrees Fahr. there was in every case a decrease in toughness, due presumably to the formation of martensite at that temperature. Further increase in the drawing temperature would of

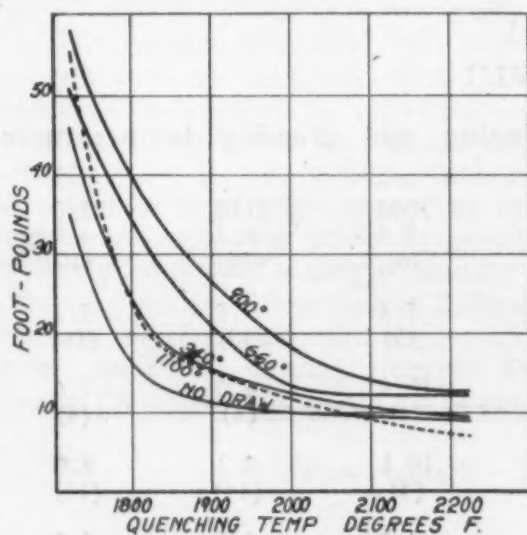


Fig. 3—Impact Values versus Quenching Temperatures 13 per cent Tungsten Steel.

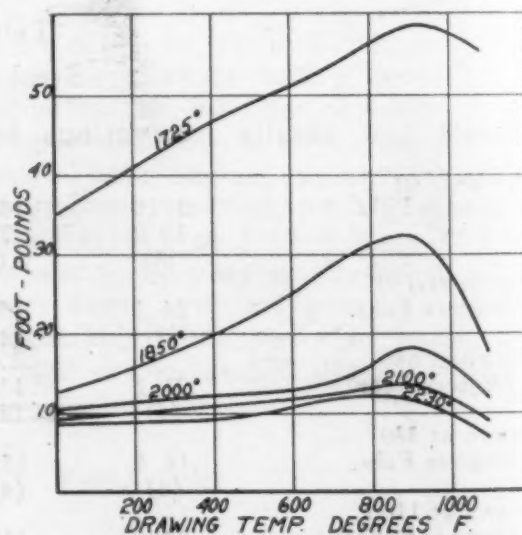


Fig. 4—Impact Values versus Drawing Temperatures 13 per cent Tungsten Steel.

course cause these curves to rise once more when the final annealing effect began.

In the case of steel 13, the general character of the behavior of the steel was about the same as for steel 18. The steel was a much



tougher one, any particular heat treatment giving much higher impact values to steel 13 than the same heat treatment would give to steel 18. This is evident from Table II, which lists the impact figures found for steel 13. These values are plotted in Fig. 3, which shows foot-pounds vs. quenching temperatures, and is comparable with Fig. 1. Fig. 4, which is comparable with Fig. 2, shows the foot-pounds plotted against drawing temperatures. The curves are seen to have the same general character as in the case of steel 18, but are placed higher on the scale.

These data, when considered in connection with the hardness, may indicate the heat treatment for particular problems where certain combi-

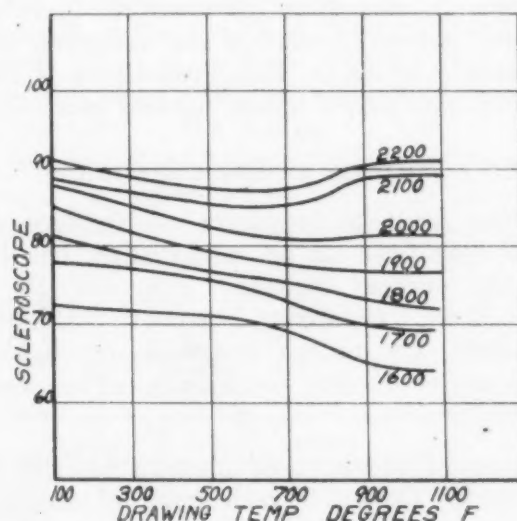


Fig. 5—Scleroscope Hardness versus Drawing Temperatures High Speed Steels.

nations of hardness and toughness are desired. The hardness developed follows in general the curves shown in Fig. 5, which are plotted from data not given here. The character of these is well known, and is given here only for comparison. The secondary hardness begins to show a pronounced development for quenching temperatures above 2000 degrees Fahr. Below this temperature it shows only in that the hardness does not drop further in drawing from 900 to 1100 degrees Fahr. It is of interest to note that the secondary hardness (that is, its accompanying brittleness) shows markedly in the toughness curves for all quenching temperatures.

The author desires to express his appreciation of the co-operation of Mr. Wm. H. Wills, Jr., in the securing of some of the data presented in this paper.

FURNACE ATMOSPHERES AND THEIR RELATION TO THE  
FORMATION OF SCALE

By George C. McCormick

## ABSTRACT OF PAPER

*This paper records experimental data and procedure during the investigation of the scaling activity of oxidizing, neutral and reducing atmospheres during the heat treatment of steel. The scale which was formed on low medium and high carbon steels when heated to various temperatures and under varying conditions of furnace atmospheres, has been determined quantitatively. Under certain conditions, oxidizing neutral and reducing atmospheres permit of the formation of scale. This conclusion is supported by the data obtained and may dispel some popular misconceptions.*

## Purpose of Investigation

A PERUSAL of the available literature on furnace design and operation renders apparent that little or no information has been published which pertains directly to the subject caption. Undoubtedly, much research has been conducted in this field. Believing, however, that the information secured is not widely distributed, the writer assumed the task of investigating the phenomena of scaling under diverse conditions. The results of these investigations are hereinafter reported.

An important chemical property of metallic iron is its tendency to combine with oxygen. Under favorable conditions of atmospheric humidity and temperature, rust, a compound of iron and oxygen, forms with speed and facility. At the higher temperatures, commonly encountered in forging and heat treating, the activity of these two elements is greatly accelerated with the result that a compound very different from iron rust is formed. This compound is generally known as scale. The chemical composition of scale is variable and complex. It is sufficient for this discussion to bear in mind the significant fact that scale is a compound of iron and oxygen, formed in the temperature ranges of thermal treatment. This experimental work was conducted for the purpose of determining, first, the temperature at which scale begins to form, and secondly, the extent of scaling at common heat treating temperatures.

## Procedure

A series of blocks were cut from low, medium and high carbon steels. Special attention was devoted to the cutting of the blocks in order that they should possess as nearly as possible the same dimensions and weight. The specimens were polished on a fine wheel, cyanided for 10 minutes at 1450 degrees Fahr., quenched in water and cleansed in a hot soda solution. This procedure served to remove the mill scale, rust or grease with which the surface of the bar stock may have been coated. The sample pieces were then carefully calipered and weighed.

The several grades of specimens were heated simultaneously in an electric muffle furnace for 1 hour each at different temperatures ranging from 900

A paper to be presented at the Detroit Convention October 2-7. The author, George C. McCormick, assistant metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.

to 1700 degrees Fahr. The gases in the furnace at all times corresponded in analysis to the atmosphere of the room, which was:

Oxygen, 20 per cent  
Carbon Dioxide, 0.2 per cent  
Carbon Monoxide, nil  
Nitrogen, 79.8 per cent by difference.

On removal from the furnace, the specimens were rapidly quenched in oil, the quantity of scale was then determined.

#### Method for Determining Scale

In determining the weight and thickness of the scale, it is mandatory to effect a complete removal of the oxidized layers without removing any metallic iron. Experiments were made with several chemical methods each of which were subject to the same criticisms—excessive removal of metallic iron or failure to completely remove the oxides.

A method was suggested of heating in cyanide for 10 minutes at 1450 degrees Fahr. followed by water quenching and cleansing in soda solution. This procedure was found to be conspicuously successful. The scale was

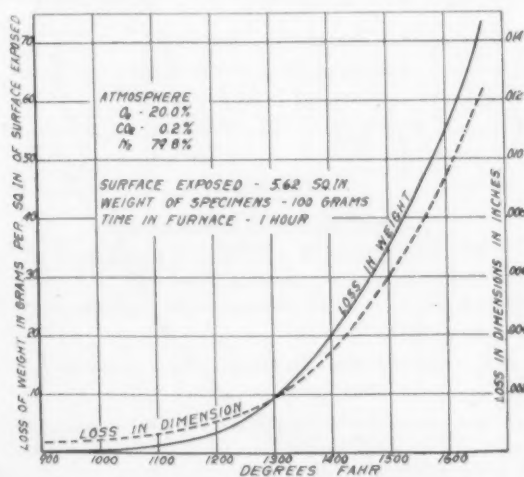


Fig. 1 Extent of scaling or oxidation on a 0.10-0.20 per cent carbon steel. It will be noted that the amount of scale formed below 1200 degrees Fahr. in 1 hour is practically negligible. Above this temperature the curve rises rapidly and at 1600 degrees Fahr. the specimen scaled on the average of 0.55 grams per square inch of surface exposed, and lost approximately .009 inch in each dimension.

completely removed by this unique application of cyaniding and specially prepared specimens cyanided in this manner, showed variations of dimension and weight so small as to have no effect upon the final results.

Fig. 1 is a graphical presentation of the extent of scaling on a 0.10-0.20 per cent carbon steel. Attention is called to the fact that below 1200 degrees Fahr. the amount of scale formed in 1 hour is practically negligible. Above this temperature, however, the curve rises rapidly and at 1600 degrees Fahr. the specimens scaled on the average 0.55 grams per square inch of surface exposed, and lost approximately 0.009 inch in each dimension.

Fig. 2 portrays the amount of scaling on a 0.50-0.60 per cent carbon steel. As in the case of the low carbon material, little scaling takes place below 1200 degrees Fahr. Attention is called to the extent of scaling at 1600 degrees Fahr. In this range, the metal scales 0.45 grams per square inch of surface exposed and loses 0.007 inches in each dimension.



In Fig. 3, the scaling of a 1.00 per cent carbon steel is depicted. As in the previous figures, little or no scale forms below 1200 degrees Fahr. In the higher temperature ranges, for example, at 1600 degrees Fahr., the steel loses 0.40 grams in weight for every square inch of surface exposed and suffers a decrease of 0.006 inches in each dimension.

### Summary of Scale Formation

From a study of these curves, it is evident that,

1. Little or no scale forms below 1200 degrees Fahr.
2. The amount of scale formed under the given conditions varies inversely with the carbon content of the steel.
3. The formation of scale increases rapidly with the rise in temperature above 1200 degrees Fahr. and at 1600 degrees Fahr. may be fittingly described as excessive.

### Kinds of Atmosphere

In furnace literature, frequent mention is made of "oxidizing," "neutral," and "reducing" atmospheres. Consideration has been given in this work to the extent of scale formation in an atmosphere containing 20 per cent oxygen. Such an atmosphere is described as "oxidizing" and permits of the

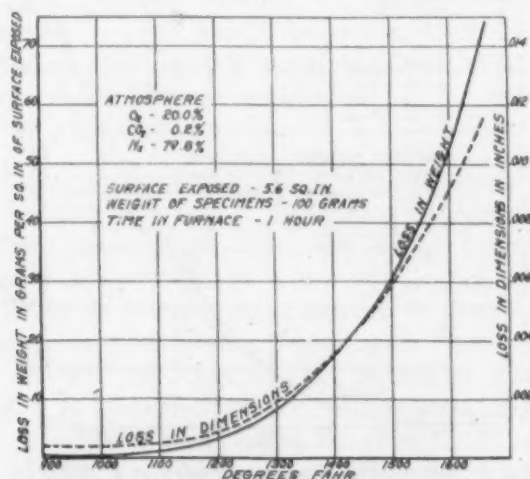


Fig. 2 Extent of scaling or oxidation on a 0.50-0.60 per cent carbon steel. As in the case of the low carbon steel very little oxidation takes place below 1200 degrees Fahr. It will be noted that the scaling at 1600 degrees Fahr. amounts to 0.45 grams per square inch of surface exposed and loses 0.007 inch in each dimension.

rapid formation of scale. Believing that certain misconceptions concerning the scaling properties of the "neutral" and "reducing" atmospheres are in existence, it is the writer's purpose to subsequently record the results of various experiments conducted in these atmospheres.

### The Neutral Atmosphere

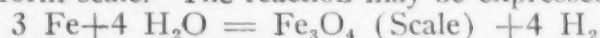
The distinctive qualities of the "neutral" atmosphere are as follows:

1. The absence of free oxygen.
2. The absence of combustible material.
3. The presence of either carbon dioxide or water vapor or both.
4. The presence of nitrogen.

It is logical, that a consideration of the effect of nitrogen, water vapor and carbon dioxide upon heated steel will throw light upon the non-scaling properties of the "neutral" atmosphere.

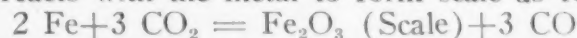
**NITROGEN**—Since scale is an oxide of iron, it is evident that nitrogen will not enter into the formation of scale and may be dismissed from the discussion.

**WATER VAPOR**—Chemistry has established beyond the shadow of doubt that when heated in the presence of iron, water vapor dissociates and reacts with iron to form scale. The reaction may be expressed as follows:



Thus, the second constituent of the so-called "neutral" atmosphere is capable of producing scale.

**CARBON DIOXIDE**—When heated in the presence of metallic iron breaks down and reacts with the metal to form scale as follows:



To establish the validity of this equation, experiments were conducted in which cylindrical pieces of steel were heated in a very slow current of pure

**Table I**  
**Scaling in Dry Carbon Dioxide**

Specimens heated from room temperature to 1600-1700 degrees Fahr. and cooled slowly.

Experiment Number	Time at 1600-1700 Degrees Fahr.	Loss of Dimension in inches	Loss of Weight in Grams per square inch of Surface Exposed
1	2 hours	0.005	0.32
2	1 hour	0.003	0.19

**Table II**  
**Reducing Atmosphere**

Extent of Scale Formation in Reducing Atmosphere—Analysis of Gases in Furnace Chamber:—Carbon Dioxide—15 per cent; Oxygen—0 per cent; Carbon Monoxide—0.4 per cent.  
Temperature 1700 degrees Fahr. Time 1 hour

Material	Loss of Dimension in inches	Loss of Weight in Grams per square inch of Surface Exposed
Low Carbon Steel.....	0.014	0.70
Medium Carbon Steel.....	0.010	0.59
High Carbon Steel.....	0.008	0.57

dry carbon dioxide. The specimens were accurately weighed before the experiment and again after the scale which formed was removed by cyaniding. In the first experiment, the samples were placed in a slow stream of dry carbon dioxide at room temperature, heated rapidly to 1600-1700 degrees Fahr., held for 2 hours, and cooled slowly. The flow of carbon dioxide was maintained constant throughout the experiment. The second experiment was similar to the first with the exception that the time at 1600-1700 degrees Fahr. was 1 hour. Reference to Table I will indicate that the quantity of scale formed under the above conditions is quite appreciable. It is evident therefore, that carbon dioxide is capable of producing scale on heated steel.

#### *The Presence of Carbon Monoxide*

In considering the above experiments, it should be borne in mind that the gas introduced into the apparatus was pure dry carbon dioxide. Analysis of the gases issuing from the furnace revealed the presence of carbon monoxide. The percentage of carbon monoxide increased with the temperature from 2 per cent between 1100 and 1200 degrees Fahr. to 13 per cent

at 1600-1700 degrees Fahr. Regardless of the presence of carbon monoxide in the furnace, the fact remains that scale formed.

### *Summary of Neutral Atmosphere*

The neutral atmosphere therefore contains two compounds, water vapor and carbon dioxide, which are active in the formation of scale. It is obviously an error to associate non-scaling properties with the neutral atmosphere.

### *The Reducing Atmosphere*

The occurrence of a "reducing" atmosphere will be identified with the following conditions:

1. The presence of combustible material.
2. The absence of free oxygen.
3. The presence of either carbon dioxide or water vapor or both.
4. The presence of nitrogen.

For the purpose of determining the non-scaling properties of an artificial reducing atmosphere, experimental work was conducted in which pieces of steel were heated in mixtures consisting of dry carbon dioxide and illuminating gas. In the first experiment polished specimens were heated from room temperature to 1600-1700 degrees Fahr., held for 1 hour and allowed to cool slowly to room temperature. During the entire time of the experiment, the

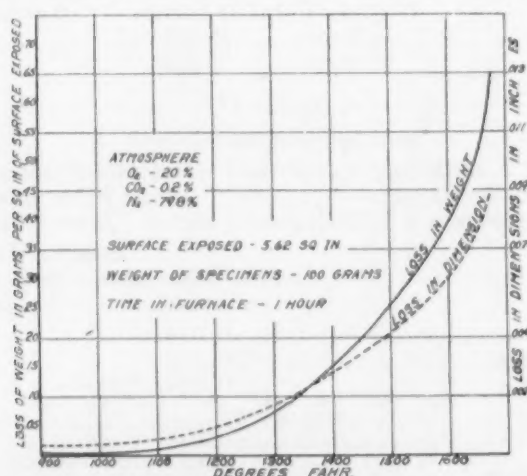


Fig. 3 Extent of scaling or oxidation on a 1.00 per cent carbon steel. Practically no scale forms below 1200 degrees Fahr. At 1600 degrees Fahr. the steel loses 0.40 grams in weight for each square inch of surface exposed and suffers a decrease in each dimension of 0.006 inches.

mixture of carbon dioxide and illuminating gas introduced into the apparatus was maintained constant at 63 per cent carbon dioxide and 37 per cent city gas by difference. No scaling was manifest on the pieces as they were removed from the furnace. The pieces retained traces of the original polish and were colored the dull bluish grey which is characteristic of carburized parts—an appearance with which all steel treaters are familiar. An additional experiment was conducted in which the percentage of illuminating gas was reduced to 10 per cent yielded very similar results. No scale was formed, and again the pieces had the appearance of having been carburized. These experiments on artificial reducing atmospheres renders apparent that it is possible to heat steel in mixtures of carbon dioxide and illuminating gas without the formation of scale. Such atmospheres may be correctly described



as non-scaling. However, the quantity of excess gas used in these experiments is prohibitive from the standpoint of both hygiene and economics.

### *Practical Reducing Atmospheres*

In order to determine the scaling activity of reducing atmospheres in furnace operating under regular shop conditions, numerous experimental observations have been carried out. Test pieces of low, medium, and high carbon steel were held in a surface combustion furnace for 1 hour at 1700 degrees Fahr. The atmosphere in the furnace was slightly reducing and analyzed as follows:

Carbon dioxide, 15 per cent

Oxygen, 0 per cent

Carbon monoxide, 0.4 per cent

On removal from the furnace the pieces were rapidly quenched in water.

**Table III**  
**Reducing Atmosphere**

Extent of Scale Formation in a Reducing Atmosphere—Analysis of Gases in Furnace Chamber:—Carbon Dioxide—11.5 per cent; Oxygen—0 per cent; Carbon Monoxide—0.8 per cent.

Temperature 1700 degrees Fahr.

Time 1 hour

Material	Loss of Dimension in inches	Loss of Weight in Grams per square inch of Surface Exposed
Low Carbon Steel.....	0.007	0.41
Medium Carbon Steel.....	0.005	0.38
High Carbon Steel.....	0.004	0.35

**Table IV**

### **Comparison of Reducing and Oxidizing Atmospheres**

Scaling in Oxidizing Atmosphere  
20 per cent Oxygen at 1675 degrees Fahr.  
Time 1 hour

Scaling in Reducing Atmosphere  
Carbon Dioxide—11.5 per cent; Oxygen  
—0 per cent; Carbon Monoxide—0.8 per  
cent. At 1700 degrees Fahr. Time 1  
hour

Material	Loss of Dimension in inches	Loss of Weight Grams per square inch of Surface Exposed	Loss of Dimension in inches	Loss of Weight Grams per square inch of Surface Exposed
Low Carbon Steel	0.013	0.75	0.007	0.41
Medium Carbon Steel.....	0.012	0.70	0.005	0.38
High Carbon Steel	0.009	0.65	0.004	0.35

The scale was determined by the cyaniding method previously described. Reference to Table II will show that the specimens scaled to an appreciable extent. Further work was conducted in an atmosphere containing a higher percentage of combustible gas. The analysis of this atmosphere yielded:

Carbon dioxide, 11.5 per cent

Oxygen, 0 per cent

Carbon monoxide, 0.8 per cent

Low, medium and high carbon specimens were used, and the general procedure was identical with the preceding experiment. The results are summarized in Table III.

By comparing Tables II and III, it will be noted that the quantity of

scale formed decreases with the increase in the percentage of reducing gas carbon dioxide present.

#### *Comparison of Oxidizing and Reducing Atmospheres*

Table IV has been prepared to show the comparative scaling activity of the oxidizing atmosphere containing 20 per cent oxygen and the reducing atmosphere.

Carbon dioxide, 11.5 per cent  
Carbon monoxide, 0.8 per cent  
Oxygen, 0 per cent

A survey of the Table IV will make evident that the scaling activity of the reducing atmosphere at 1700 degrees Fahr. is only half as intense as the scaling activity of the oxidizing atmosphere. Several experiments have been conducted in which small pieces of tool steel were held from 10 to 15 minutes at 1400-1600 degrees Fahr. in reducing atmospheres. The pieces were discolored but no measurable quantity of scale formed. It, therefore, appears logical to conclude that regardless of the presence of carbon dioxide in the furnace atmosphere, scaling will take place when the temperature is sufficiently high and the time of heating is sufficiently long.

#### **Conclusions**

As a result of the data obtained in the foregoing investigation the following conclusions are drawn.

1. In an atmosphere containing 20 per cent oxygen, little or no scale forms on steel exposed to a temperature of 1200 degrees Fahr. for 1 hour.
  2. For straight carbon steels heated under identical conditions, the quantity of scale formed varies inversely with the carbon content of the metal.
  3. The formation of scale becomes appreciable at 1200 degrees Fahr. in atmospheres containing 20 per cent oxygen, and from that point increases rapidly. At 1600 degrees Fahr., the quantity of scale formed may be fittingly described as excessive.
  4. The neutral atmosphere, because of the carbon dioxide and water vapor which it contains, is active in the formation of scale.
  5. Steel may be heated in mixtures of carbon dioxide and illuminating gas without the formation of scale. Such gaseous mixtures may be correctly described as non-scaling.
  6. Reducing atmospheres, found under actual operating conditions, permit the formation of scale when the temperature is of sufficient intensity and when the time of heating is of adequate duration.
  7. Pieces of steel may be heated for a short time in reducing atmospheres without the formation of appreciable quantities of scale.
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## THE TESTING OF METALS FOR HARDNESS

By S. P. Rockwell

THE term "hardness" is ambiguous and is rather indefinite in its meaning. We know that certain hardness tests show some materials to be hard, yet they can be filed or machined. High speed steel, for instance, by testing is found to be hard and yet soft to the file. Manganese steel can be sheared but cannot be machined. By the Brinell method of testing it is soft, but by the scleroscope method it is hard. Sealing wax by the scleroscope shows as hard as mild tool steel yet, when tested by the Brinell method, it flows and no reading can be taken. It evidently follows that the various hardness testers measure various properties of hardness. Hardness may be expressed by six ideas.

1. Cutting hardness, or the resistance of metals to various cutting operations. Knoop drill test was developed for use on castings to test this quality.

2. Abrasive hardness, or the resistance of metals to wear when subjected to rotative or sliding motion. In bearing metals this is measured by the sclerometer. Various special machines have been developed to test the wear caused by various load and lubrication conditions.

3. Tensile hardness, or the strength of metals in terms of elastic limit and ultimate strength, when such metals are ruptured, is determined in the ordinary universal testing machine.

4. Rebound hardness, or the elastic properties of the metal when allowed to strike and rebound. The scleroscope is the usual method of measuring these properties.

5. Indentation hardness, or the resistance metals offer to indentation. The Brinell method measures this property in terms of plasticity and the Rockwell in either terms of plasticity or density.

6. Deformation hardness, or the distortion properties of sheet metal. The Erichsen tester is used for this purpose by forcing the work through a die and measuring the distance it can be drawn before rupture.

This paper will deal with tests made on standard Brinell, Scleroscope and Rockwell hardness testing machines.

## Adaptability of the Various Testers

*The Rockwell Hardness Tester*

The Rockwell hardness tester is at present made in three sizes, the Model 2A has an opening between chuck and testing point of  $2\frac{1}{4}$  inches between the point of test and the frame 3 inches. The Model  $2\frac{1}{2}$ A,  $4\frac{1}{2}$  and 5 inches. The Model 3A, 7 and 5 inches. All materials which can be accommodated in the respective openings can be tested. All models will test sheet steel on a comparison basis to 0.010 inches thick, brass on a comparison basis to 0.015 inches thick. Models 2A and  $2\frac{1}{2}$ A will test steel wire on a comparison basis to  $1/16$  inch in diameter and brass wire on a comparison basis to  $3/32$  inches in diameter. Model 3A is not recommended for such small diameters, as low as  $3/8$  inches diameter wire or rod, however, it may be tested.

Absolute parallelism of test surface to test point is not necessary. The angle depends a good deal on the metal hardness and the danger of slippage

A paper presented before the Indianapolis Convention. The author, S. P. Rockwell, is consulting metallurgist, Hartford, Conn.



or creep of the test specimen on the chuck. Polished surfaces are not necessary as light reflection is not a function of the hardness reading. Considerable surface scale does not materially affect readings as the minor pressure forces the testing point through this to the true metal beneath.

Hollow specimens may be tested with as great a degree of accuracy as solid objects. The limit is only controlled by whether the object is permanently deformed by the major pressure. Even in this case a special chuck or mandrel can be used to eliminate permanent shape deformation. Rollers, bushings and short tube lengths may be tested on either the outside or the inside. When tested on the inside a goose-neck chuck is used and the test point is placed in this. Axes can be tested within  $\frac{1}{8}$  inch or closer to the cutting edge on Model 2 $\frac{1}{2}$ A with a special form of fixture. Taps may be

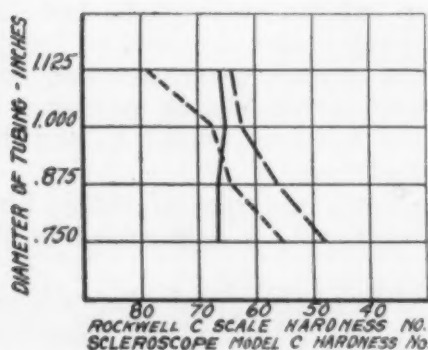


Fig. 1 Effect of the mass of the chuck in testing hardened, carburized steel tubing. Solid line—Rockwell test C scale. 120 degree diamond 150 kilogram pressure. Dotted line—Model C scleroscope on a V chuck. Dash line—Model C scleroscope on standard flat chuck.



Fig. 2 Dial indicating hardness of metals when tested by the Rockwell tester. B—Scale is read when using  $\frac{9}{16}$  inch steel ball with a 100 kilogram load. C—Scale is read when using a 120 degree diamond cone with 150 kilogram pressure.

tested on the teeth by the use of centers and a quick moving support. In fact nearly everything requiring a test for hardness can be tested with the proper method of chucking.

The effect of mass of the chuck, providing it does not permanently deform or creep under the major pressure, has no effect on the hardness reading. See Fig. 1. The principle of the test allows for future possibilities in designing machines to test large gears, etc., that are in themselves too bulky to move. The weight of the testers vary from 55 pounds for Model 2A to 70 pounds for Model 3A. This weight makes it possible to grasp it by one hand and carry it about as desired. There is no need for leveling the instrument up, it operates correctly when set on the ordinary bench or table.

The speed of the operation depends on the operator, and the requirements of the test. If hardness comparison is to be made with tests conducted at another plant, 10 to 12 accurate tests may be made a minute. If inspection only is required, such as sorting, comparing, etc., 25 to 30 tests may be made a minute. The depth of impression is so slight that there are few objects found that cannot stand the small indentation made. The impression made in a ball race would not be wise. Due, however, to the accurate control of the point of test, a race can be tested just out of line of the ball travel.

The Rockwell tester beside being furnished with a considerable range of chuck, shapes, standard test blocks, etc., is equipped with 3 different weights

which apply loads of 60, 100 and 150 kilograms as they are desired for the different test points. The Brinell range is about 160 to 170 and up, and the scleroscope range is from 12 up. The readings are taken on the black figures of the C scale on the dial indicating the hardness. See Fig. 2. The load to be used with the diamond cone is the 150 kilograms load. A Rockwell reading then prefixed with the letter C is a standard reading and indicates the use of the diamond cone as the testing point and 150 kilograms as the major load. The minor load is 10 kilograms under all conditions of tests and the time 5 seconds. The 1/16 inch ball is for use on nearly all metals which have a range of good machinability to extra soft. The Brinell range is 50 to 220, and the scleroscope range up to 55. The readings are taken on the red figures of the B scale on the dial. The load to be used with the 1/16 inch ball is 100 kilograms load.

The Rockwell hardness number on the C scale (which scale applies when the diamond cone of 120 degrees angle and the 150 kilogram major load are used) is based on the depth to which the 150 kilogram major load drives the point below the depth to which it was initially driven by a 10 kilogram minor load. A direct measurement of the depth of impression would give a higher number for softer material, and so to conform to the accepted custom of a higher hardness number for harder materials, the depth indicator has the numbering in retrogression for progressive depth so that a reading of 20 means a deeper hole than a reading of 60 and the dial (on which each sub-division is equivalent to 0.002 millimeters motion of the test point) automatically subtracts the depth reading from 100 and therefore, the complement of the depth reading is the directly indicated hardness number. In a similar manner, the Rockwell hardness number on the B scale, which scale applies when the 1/16 inch steel ball and the 100 kilogram major load are used, is based on the depth to which the 100 kilogram major load drives the ball below the depth to which it was initially driven by a 10 kilogram minor load. If, however, the same scale on the dial was used, as is used for the diamond cone and the 150 kilogram load, there would be occasions when testing soft metals that the pointer would register less than zero. To avoid the confusion that might arise from having a minus or negative reading, the starting point has been moved 30 subdivisions. This means instead of starting the test at zero, it is started at 30. The steel ball would not hold its shape in tests on very hard steel and is not used for such tests and this together with the desire to spread the working range of the steel ball over a full revolution of the dial pointer has made it advisable to eliminate from the steel ball or B scale, readings that apply to shallow depth. This permits bringing into the range of the dial, the measurement of particularly deep impressions on very soft material without having such readings fall below zero hard. This is the reason that B-zero and B-100 are not at the top of the scale as C-zero and C-100 are, but are down in the southwest corner. If this were not done, readings from B-30 to B-zero could not be conveniently recorded inasmuch as they would be negative readings and lead to confusion. The numbering is retrogressive, as previously explained, for the C scale, only in this case, the depth reading is automatically subtracted from 130.

A Rockwell reading then prefixed with the letter B is a standard reading and indicates the use of the 1/16 inch ball as the testing point and 100 kilograms pressure as the major load. The life as regards permanent deformation of the 1/16 inch ball is increased if metals no harder than B-100 on the Rockwell scale are tested. By discarding such balls as have been used on

harder metals a greater degree of accuracy can be maintained. The 1/16 inch ball is a standard article and is made to size by a number of ball manufacturers. There are other materials which can be tested satisfactorily with any of the test points and with any of the loads. These materials might be die castings, fibre, etc. Any combinations of the points and loads not mentioned above would then be special cases and as such the test condition should always be stated so that comparison may be made. For instance, a test with a 1/8 inch ball with 60 kilograms major load read on the B scale would be recorded thus—1/8-60 B56, etc.

A further application of the Rockwell hardness tester with steel balls as testing points is in using the same as the Brinell machine, that is making the impression and measuring the diameter of the impression as a hardness number and computing to Brinell numbers. The impression diameter is easily read by using the ordinary Brinell microscope in place of the regular eyepiece of any ordinary microscope fitted with a 32 millimeter objective. This method is not recommended as it is not necessary. It, however, can be used where one wishes to use various hardness determinations, etc. This method is similar to the Baby Brinell method and the same microscope may be used.

The diamond has the ability to resist pressure with a minimum of wear. Diamond tipped tools have demonstrated this. Care should be used that no sudden blow is given them, as a fracture may be started.

#### *The Shore Scleroscope Tests*

The scleroscope is now regularly made in three models, C, C1 and D. Model C is in most general use, then D. Model C1 has recently been placed on the market. The writer has as yet not used this instrument.

The scleroscope as furnished is equipped with a diamond tipped hammer, a set of test blocks to check the proper operation as regards the setup and diamond condition, a standard frame and chuck to hold the scleroscope proper and to test small objects not over 2 inches thick. The scleroscope proper may also be removed from its frame and attached to a swing arm so that very large objects are readily tested. A leveling device is attached so that the instrument may be set vertical.

The scleroscope decreases in its efficiency in detecting hardness changes as the hardness of the test work decreases. To rectify this condition a steel hammer can be procured called a magnifying hammer. This is to be used on soft work. This throws the hardness units into a different scale. Due to the repeated blows this hammer receives, it in itself changes hardness and must be replaced occasionally or else the results are misleading. The scleroscope test is affected in its readings by—

1. Mass and shape of piece being tested. See Fig. 1.
2. Mass of chuck under specimen. See Fig. 1.
3. Hardness of chuck under specimen.
4. Smoothness and cleanliness of surface of test piece.

The Model D is apparently affected more by these conditions than is the Model C. In using the scleroscope the conditions of test should always be noted by the model used, the method of chucking, a sketch of the piece tested, and where, noted on it. If this were always done there would be less confusion in interpreting results.

The Bureau of Standards report, "In working with the scleroscope it was found that the hammer must be calibrated after a certain number of tests. For this purpose a piece of steel hardened to 100 scleroscope must be used. The rebound for any given steel cannot be corrected by proportionate decrease or increase if the hammer gives a rebound either less or greater



than 100 on the hardened steel. This shows that a slight change in the form of the hammer assigns the metal tested to a different position in the hardness scale."

It is the diamond in the hammer that is eventually damaged by the sudden shocks it receives. The prolongation of the diamond's life can be secured by never testing twice on the same spot and this will prevent the diamond striking super-hard metal.

#### *The Brinell Test*

There are a great many types of Brinell testers. They are, as a rule, supplied with a series of weights to give loads from 500 kilograms up to 6000 kilograms. The dead weight testers, however, can be used for any intermediate load. Any size ball and under nearly any load condition can be used. The standard for Brinell test is the  $10 \pm .0025$  millimeters steel ball with 3000 kilograms load for hard metals and 500 kilogram load for soft metals, the time 30 seconds. Due to a variance in deformation of balls under different loads, the different test conditions assign the piece tested to a different hardness scale. It is always best in giving Brinell hardness to note the conditions of test.

A microscope and a marked scale for calibrating is, as a rule, furnished with the tester to measure the diameter of the impression which is the unit of hardness. Many plants are using this unit to specify their hardness as it saves time in computing or comparing with a chart to determine the Brinell number, which increases rapidly with each unit increase in actual hardness. The errors are due to poor light reflection to the microscope, and to ball flattening. Where very accurate results are desired, a new ball is used for every test and the diameter of the impression is read twice at right angles and the average taken as the hardness unit. Commercially this is seldom done. Usually due to the time consumed in making a test only one impression is made. As it is the exception to find a piece of metal of uniform hardness it is often wise to take several readings if conditions warrant. As the reading of hardness depends on the reflection of the indentation back to the eye through the microscope, a bright surface must be made on the metal tested and this is usually done by polishing lightly with emery. On rounded articles a flat surface is prepared by grinding. If the test surface is flat the indentation will be circular and error in this case is lessened.

A number of makers of standard Brinell machines have developed depth reading devices. These have not been generally accepted for two reasons; first, no reliable conversions were worked out between depth and diameter of indentation, and second, because the average Brinell tester is not delicate enough in its load application to apply a constant minor pressure before and after test.

The greatest thickness of metal which can be tested by the Brinell testers depends only on the design of the tester itself. As regards thin sections, roughly accurate results cannot be secured on specimens which are less than 16 times the impression depth. Much thinner pieces may be tested for comparative results, in which case the metal tested is assigned to a different position on the hardness scale. Parts which cannot stand the load applied without permanent deformation, can often be tested only at the loss of the part. High speed steel tools should never be tested with the Brinell as hardened high speed always cracks radially from the indentation.

#### **Description of Operation of Testing Machines**

##### *The Rockwell Test*

The Rockwell test consists of impressing a hard object (harder than the

metal tested) into the metal, and noting the depth of indentation. The test points and weights used are of small size so that no more damage is done to the work than is absolutely necessary in order to make the test. The small size test point also makes it possible to test on very small areas. As the curvature of the point is small, concave and convex surfaces of very small radius may be tested accurately. As the measurements of depth are very small, they are magnified through a 5 to 1 lever to a 100 to 1 indicating dial. This means that each unit on the dial is 0.002 millimeters, or approximately 0.00008 inch. This again means that the actual depth of penetration or marring on the softest steel is only about 0.2 millimeters, or .008 inch.

Where such close measurements are used, it is necessary to have a definite minor pressure of application of test point against work, which is to remain constant at the beginning and end of depth measurement. This is analogous to the ratchet stop with the micrometer. This is done by a calibrated spring in the head of the machine. This spring is under compression at all times. Its total action under test is confined to about 1/16 inch action during which time its difference of exerted pressure is negligible.

The work to be tested is placed on the chuck and a clockwise rotation of the hand wheel raises the work in contact with the testing point. At this moment the minor pressure begins to apply. The handwheel motion is continued until the ferrule on the dial approaches the line on the stem. The pointer now stands somewhere in a vertical position, or if not, the handwheel can be turned further to cause the pointer to be nearly vertical. The dial is then turned (if necessary) in order to bring the C-zero, or arrow on the dial to coincide with the pointer. The minor pressure is then fully applied.



Fig. 3 Diagrammatic sketch of the process of indenting while testing a specimen with the Rockwell tester.

Reference to Fig. 3 will show this and the following functions of the test. The minor pressure causes a slight penetration of the test point into the steel which point is used for an index mark zero.

By touching a small button at the right of the machine, a clockwork mechanism is set in motion which slowly lowers a weight on the left of the machine. This weight is called the major pressure and its actual weight is increased through a series of levers so that it is multiplied many times on the testing point itself. This load has now forced the test point further into the metal as shown in Fig. 3, and shows as  $t+m$ . This  $t+m$  is the penetration of the testing point in the work, the deflection of the work and the deflection of the testing machine. The hand lever at the right of the tester is now brought back or cocked. This winds up the clock mechanism and leaves the tester ready for another test. By bringing back this hand lever the major pressure is removed, leaving the minor pressure applied as at the beginning. This releases the deflection of the tester, the deflection of the work and leaves the testing point imbedded in the material to the exact depth of indentation Fig. 3, this depth  $t$  is shown in Rockwell hardness units on the dial. The hand-wheel is now turned counter clockwise and the test piece moved or changed for another test.

In order to control the rate of application of the major load the clock-

work mechanism is controlled by a leather clutch, the tension of which is controlled by a knurled screw inside at point of machine. The clutch should be adjusted so that the hand lever describes its arc in 5 seconds, commercially from 3 to 10 seconds may be used. The speed may be increased when very fast testing is desired. Doing this, however, causes the major pressure to exert a blow which transfers hardness to a different scale. Where the tester is used merely in sorting work this speeding up is permissible.

#### *The Brinell Method*

The Brinell tests comprise the impressing of a steel ball under a known pressure in the metal to be tested. As the diameter of the impression is the basis of the Brinell hardness unit, the test piece must be flat so as to make a circular impression and bright enough to be read by the microscope.

There are a number of different mechanical principles used in making the Brinell test. The dead weight principle where the work is forced up against the testing point until a scale beam is balanced at the desired load. The standard tensile testing machine is used in this manner. The hydraulic machine is usually used as its construction is lighter and faster in load application.

In this case the test work is placed on a chuck and a handwheel raises the work against a steel ball as a testing point. A valve in the head of the machine is then closed and a pressure is exerted on the ball through a piston by an oil hydraulic pump. A pressure gauge shows the pressure increase and as the pressure approaches that desired, the pumping should be slowed up. When the desired pressure has been obtained a balanced T lever, previously weighted, raises and after a certain height, automatically releases the pressure. This is a safety device to insure that the pressure may not be exceeded. Proper manipulation, however, requires one to raise these weights by hand just before the pressure has been secured with the hand pump, and carefully lowering them after the pressure has been obtained. This prevents an excess of weight which would cause a faulty hardness reading. This pressure is maintained from 15 seconds for hard metals to 30 seconds for soft metals. This time element is necessary on account of the plasticity of metals, and an equilibrium between the pressure of the steel ball and the steel must be obtained.

The valve in the head of the machine is now opened, which releases the pressure. The chuck containing the metal under test is then lowered and the test piece removed. The test piece is then taken to a strong light and the diameter of the impression made by the steel ball and the pressure is read twice 90 degrees apart by the aid of a microscope containing a scale. The diameters are read in millimeters, are averaged and, by the use of a chart, are converted into Brinell numbers.

The unit of Brinell hardness is .05 millimeter. The Brinell number is not a unit. On hardened tool steel, one unit is about 30 Brinell numbers and on annealed tool steel is about 4 Brinell numbers.

#### *The Scleroscope Test*

The scleroscope hardness test is made by dropping a diamond tipped hammer on to the metal to be tested and noting the rebound of the hammer. There are, in general use, two types of machines, the Model C being the older type is perhaps in most general use. A glass tube holds the hammer and serves as a guide for it. The hammer is raised to the top of the tube by air suction and maintained there by a mechanical catch. It is released by an air valve which trips this mechanical catch. A hand bulb furnishes the air to actuate the various functions in rotative order.

To operate, the instrument is carefully leveled by an attached leveling



device. This prevents friction between the hammer and the glass tube. The work to be tested is then placed on the chuck and the glass tube and its housing is lowered by rack and pinion until contact is made. By means of the air bulb the hammer is released which falls striking the test block and rebounds. The height of rebound is noted on a scale divided into 120 arbitrary equal parts at the back of the glass tube. The glass tube is now raised, and test piece moved and another test made. Extreme high or low readings are ignored and the rest averaged. The glass tube and its housing can be removed to a swing fixture so that an object too large to test on the regular chuck can be held in a vise and tested. The Model D instrument, brought out just previous to the World War, is mechanically different. The diamond tipped hammer is much heavier and in order to apply the same impact falls from a proportionately shorter distance. Its release is effected by a mechanical 3 ball clutch actuated by a knurled button. The same 3 ball clutch holds the hammer at the maximum rebound, the return of the knurled button causes their height to be measured and shown on a dial divided into arbitrary equal parts. This model may be used on a swing arm for large objects the same as Model C. The hardness units are the same. Due, however, to unexplained differences in physical impact, certain conditions of test piece shape and chucking will give different readings.

The need of leveling the instrument and the averaging of the test results is the same as for the Model C instrument.

### Tests Conducted

Seven bars, one each of the following steels were selected for test:

1. Vulcan Vanadium
2. Ketos
3. Rex A A
4. S.A.E. 2330
5. Carpenter Monitor Tool Steel
6. Carpenter Tool Steel
7. Jessop Tool Steel.

These bars were first annealed, then 1/16 inch of the surface was removed by machining and ten-thousandths by grinding to make smooth and parallel surfaces. Each bar was then cut into 13 pieces, and all hardened at the proper temperatures and in the proper quenching mediums. After hardening, 12 of the pieces were each drawn back in a Hump furnace, for thirty minutes at temperatures 320, 400, 500, respectively through 1400 degrees Fahr. Before testing, each piece was ground ten-thousandths on a side in 3 cuts of the emery wheel. To remove any surface softening which might be caused by the grinding, each piece was carefully lapped on fine emery cloth. Each piece was of sufficient thickness and mass to insure uniform testing conditions for each method of test.

The pieces were first tested on a Model C scleroscope, which was first leveled and tested satisfactorily with the 100 test block furnished. Twenty readings were recorded, the ten best readings being selected for the hardness determinations, which are recorded on Figs. 4, 5, 6, 7, 8, 9 and 10. The pieces were then tested on the Model D scleroscope, which likewise was leveled and checked. The same method was used in recording readings.

The pieces were then tested on three different Rockwell hardness testers with two diamond cone testing points. Five readings were taken under each condition and each reading used in the hardness determination as shown in

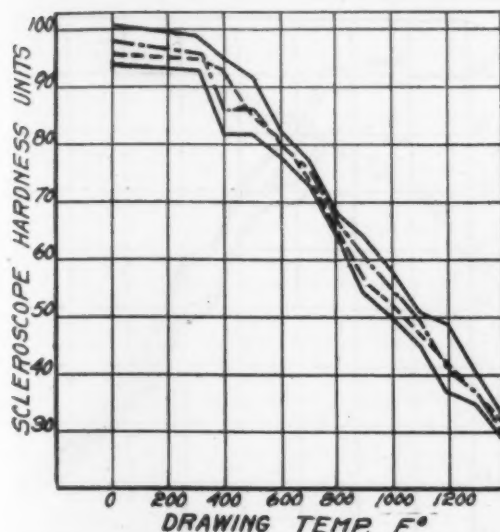


Fig. 4 Vulcan Vanadium Tool Steel. Size of specimens,  $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{3}{4}$  inches. Machined, ground, hardened in water 1450 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

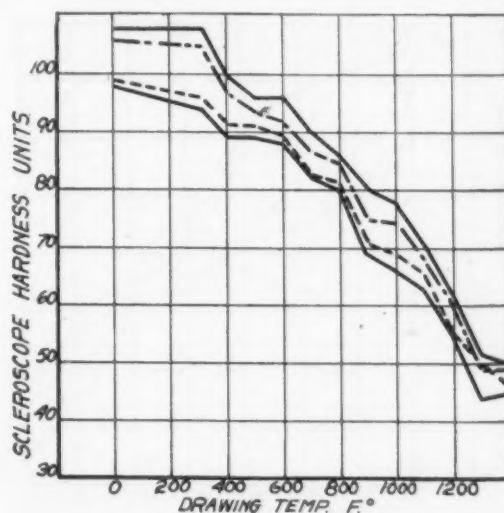


Fig. 5 Ketos Oil Hardening Steel. Size of specimens  $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{3}{4}$  inches. Machined, ground, hardened in oil 1450 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

Figs. 11, 12, 13, 14, 15, 16 and 17. Two of the Rockwell testers were new and one had been in use at least two months.

The pieces were then tested on an Olsen hydraulic Brinell machine. This

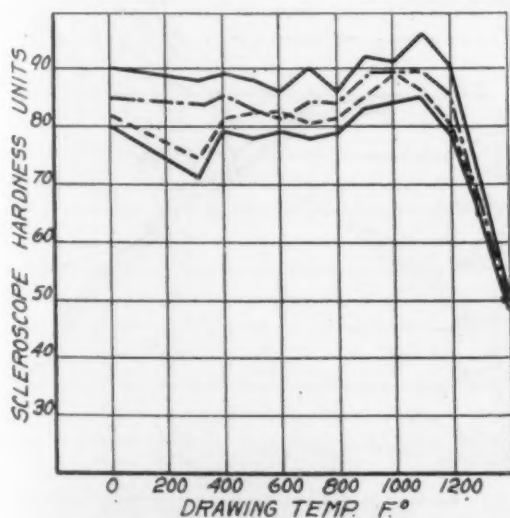


Fig. 6 Rex AA High Speed Steel. Size of specimens,  $1\frac{1}{4} \times 1 \times \frac{1}{16}$  inches. Machined, ground, hardened in oil 2300 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

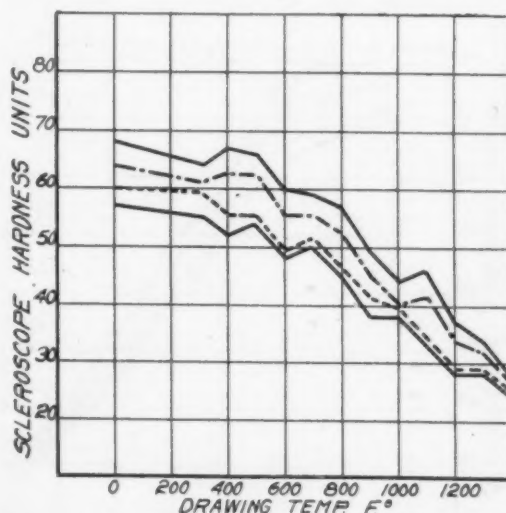


Fig. 7 S.A.E 2330 Steel. Size of specimens,  $1\frac{1}{4} \times \frac{3}{4} \times \frac{1}{16}$  inches. Machined, ground, hardened in brine 1550 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

Brinell machine is in daily use and checked satisfactorily with various other concerns. Two readings were taken, the time on all specimens was 15 seconds. The diameter was read twice at 90 degrees apart and the average used for hardness determinations as shown in Figs. 18, 19, 20, 21, 22, 23 and 24.

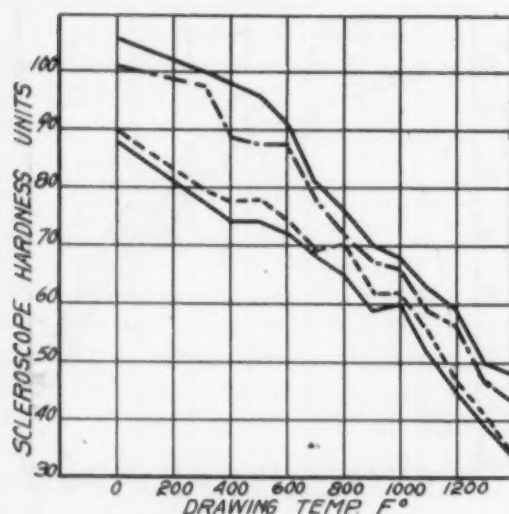


Fig. 8 Carpenter Monitor Tool Steel. Size of specimens,  $1\frac{1}{4} \times \frac{3}{4} \times \frac{1}{2}$  inches. Machined, ground, hardened in water 1500 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

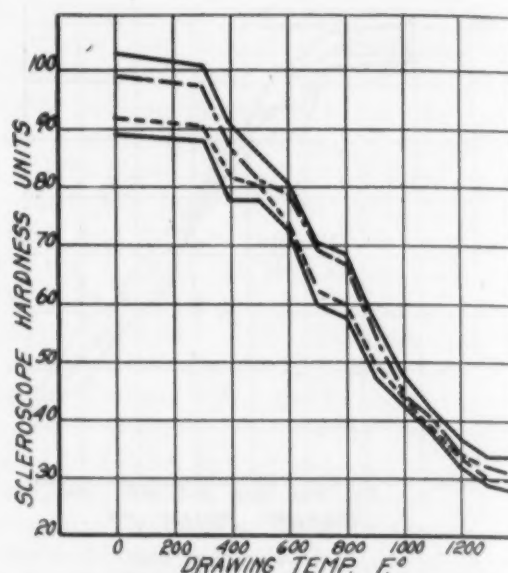


Fig. 9 Carpenter Tool Steel. Size of specimens,  $1\frac{1}{4} \times 1 \times \frac{1}{2}$  inches. Machined, ground, hardened in water 1450 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

The tests were then duplicated on a Riehle dead-weight Brinell machine, which checked with other machines. The same method was used to determine the hardness as with the previous test.

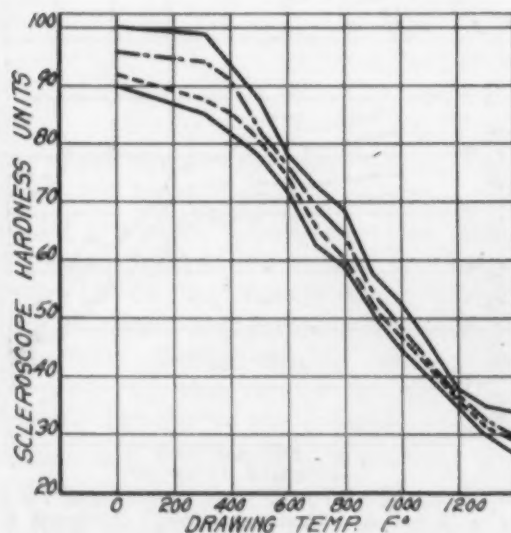


Fig. 10 Jessop Tool Steel. Size of specimens,  $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{2}$  inches. Machined, ground, hardened in water 1450 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

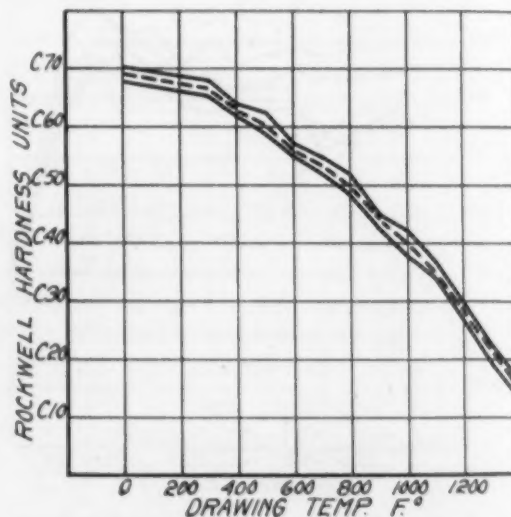


Fig. 11 Vulcan Vanadium Tool Steel. Size of specimens,  $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{2}$  inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

On the Brinell test one ball only was used for all samples tested on one type of machine. The samples drawn at 1400 degrees Fahr., were first tested, then 1300 degrees Fahr., etc. This method approximates the usual



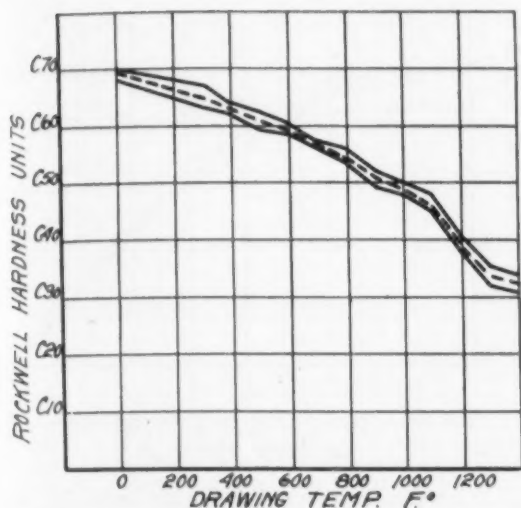


Fig. 12 Ketos Oil Hardening Steel. Size of specimens,  $1\frac{1}{4} \times \frac{3}{8} \times \frac{1}{2}$  inches. Machined, ground, hardened 1430 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

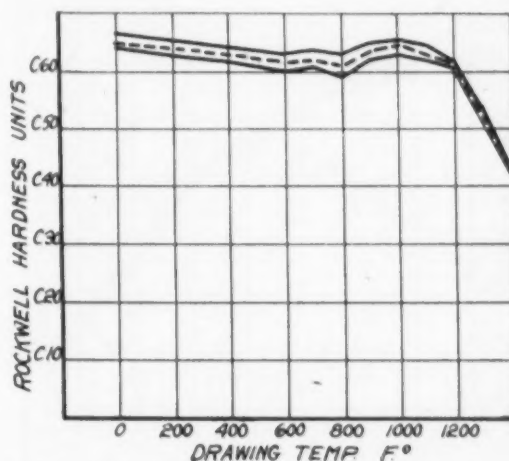


Fig. 13 Rex AA High Speed Steel. Size of specimens  $1\frac{1}{4} \times 1 \times \frac{1}{8}$  inches. Machined, ground, hardened 2300 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

commercial factory conditions of test. The harder specimens were first rubbed over lightly with Prussian blue, so as to assist in reading the diameter of the impression. The microscopes were carefully checked before tests on the

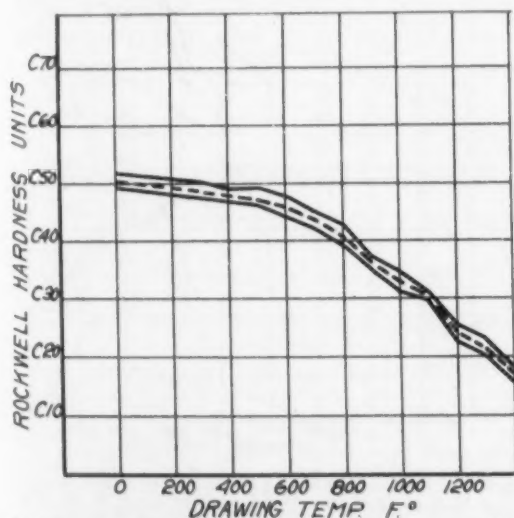


Fig. 14 S.A.E. 2330 Steel. Size of specimens,  $1\frac{1}{4} \times \frac{3}{8} \times \frac{1}{2}$  inches. Machined, ground, hardened 1550 degrees Fahr., quenched in brine, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

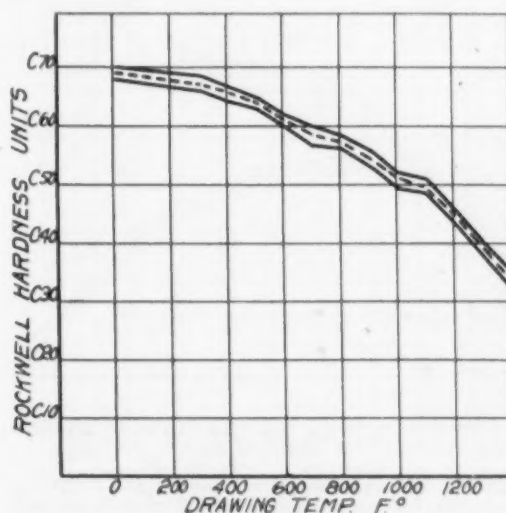


Fig. 15 Carpenter Monitor Tool Steel. Size of specimens,  $1\frac{1}{4} \times \frac{3}{8} \times \frac{1}{2}$  inches. Machined, ground, hardened 1500 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

standard scale and with each other. The impressions were made half way between center and edge of specimen. In all other tests with the scleroscope and Rockwell tester, the specimens were tested at various parts of the surface so that average conditions were obtained. All tests by scleroscope, Rock-

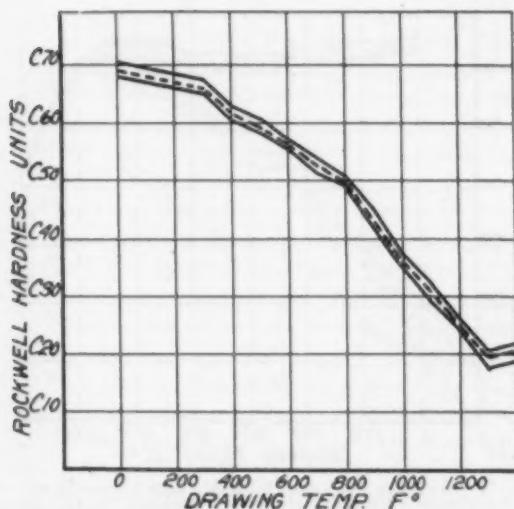


Fig. 16 Carpenter Tool Steel. Size of specimens,  $1\frac{1}{8} \times 1 \times \frac{1}{8}$  inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average value of above test conditions.

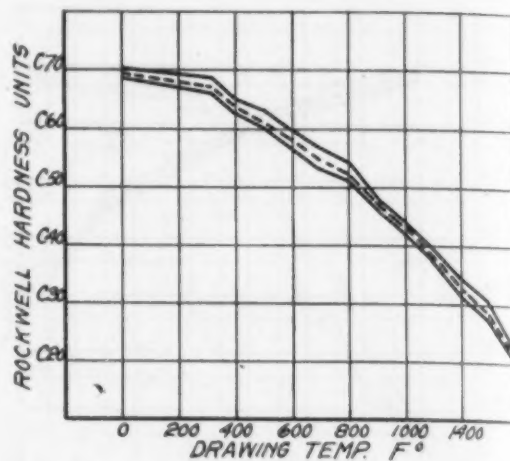


Fig. 17 Jessop Tool Steel. Size of specimens,  $1\frac{1}{8} \times 1\frac{1}{8} \times \frac{1}{8}$  inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test condition.

well and Brinell were conducted on one side of the specimen, so that good chuck surface would be assured for all tests.

### Conversion in General

In converting values determined by one form of hardness measurement to another, we must bear in mind that the conditions of a test enter into the

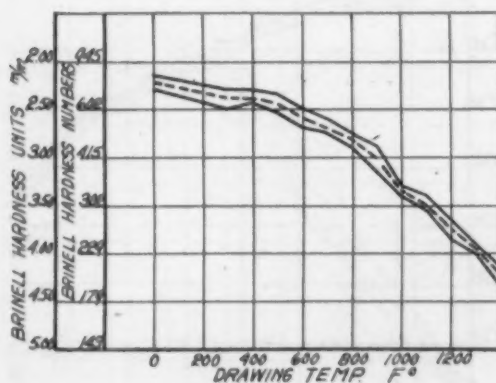


Fig. 18 Vulcan Vanadium Tool Steel. Size of specimens,  $1\frac{1}{8} \times 1\frac{1}{8} \times \frac{1}{8}$  inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

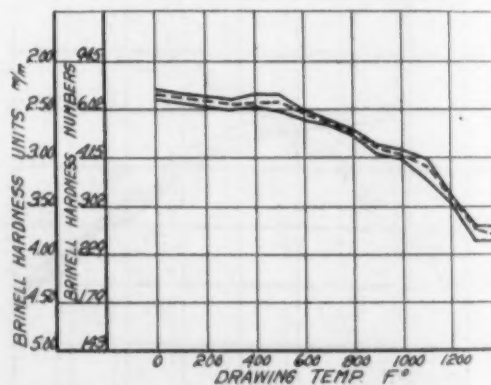


Fig. 19 Ketos Oil Hardening Steel. Size of specimens,  $1\frac{1}{8} \times \frac{1}{8} \times \frac{1}{8}$  inches. Machined, ground, hardened 1430 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

matter. The same area tested by one means can not be used for test by another means, because at the completion of the test the metal is not in the same physical forms as before. Secondly, each different method of test affects a different area of metal and at a different depth. For this reason, no one method of test can be reliably complete. Furthermore, metals compared must be as homogeneous throughout as pos-

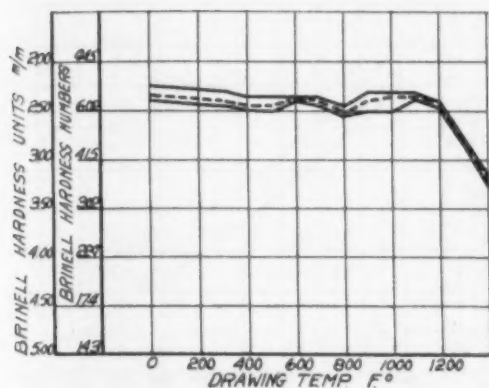


Fig. 20 Rex AA High Speed Steel. Size of specimens,  $1\frac{1}{4} \times 1 \times \frac{1}{8}$  inches. Machined, ground, hardened 2300 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

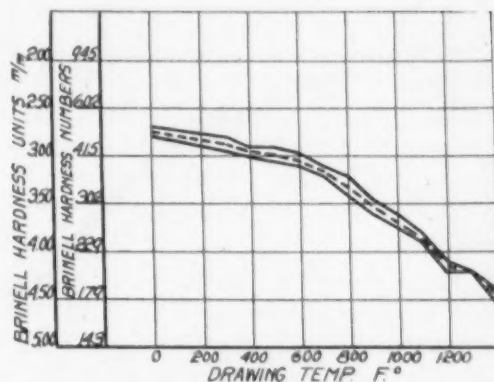


Fig. 21 S.A.E. 2330 Steel. Carbon .30 per cent Nickel 3.5 per cent. Size of specimens,  $1\frac{1}{4} \times \frac{3}{4} \times \frac{1}{8}$  inches. Machined, ground, hardened 1550 degrees Fahr., quenched in brine, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

sible. For instance, a light depth, say 1/32 inch, of carburized steel cannot be tested accurately as regards the case-hardness by the Brinell. In the case of the scleroscope, the hardness is affected by the hardness of the core. As regards the Rockwell test, if the case is not actually punched into the core, a true hardness reading is given. This reading for comparison, however, to Brinell or scleroscope, necessitates that the comparison be made to Brinell and

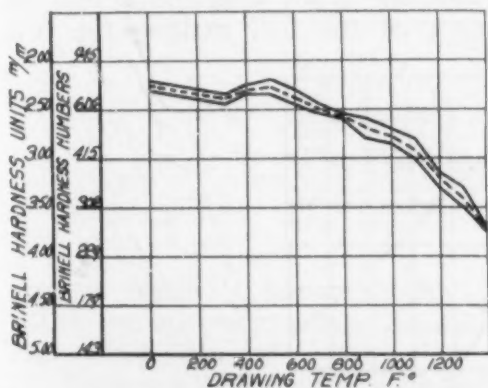


Fig. 22 Carpenter Monitor Tool Steel. Size of specimens,  $1\frac{1}{4} \times \frac{3}{4} \times \frac{1}{8}$  inches. Machined, ground, hardened 1500 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

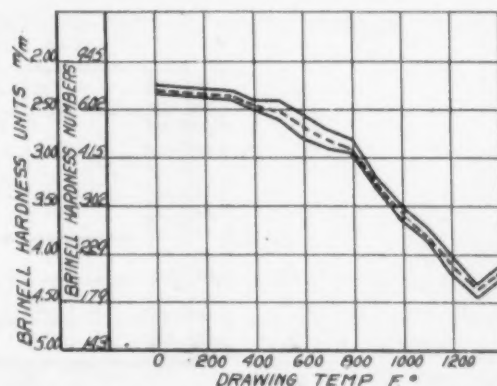


Fig. 23 Carpenter Tool Steel. Size of specimens,  $1\frac{1}{4} \times 1 \times \frac{1}{8}$  inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

scleroscope tests made on homogeneous steel and of volume enough so that metal thickness does not enter into the problem.

### Brinell Test

The formula for Brinell hardness number is  $BHN = \frac{P}{\pi D t}$  where P is

pressure applied, D is the diameter of the ball used in making the impression, and t is the depth of the impression.

The depth t in Brinell practice has not been used due mainly to me-



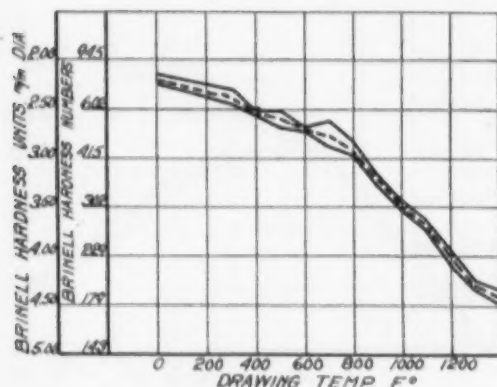


Fig. 24 Jessop Tool Steel. Size of specimens,  $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{2}$  inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

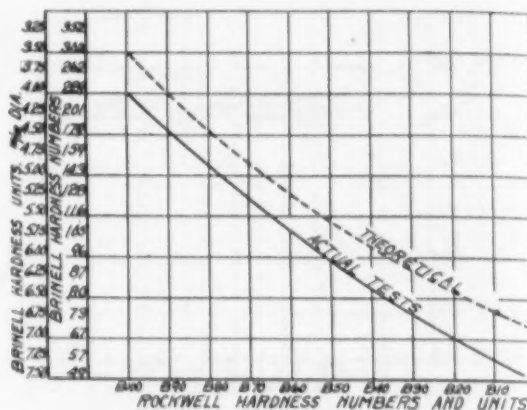


Fig. 25 Conversion chart showing theoretical and actual test data for testing common brass. Rockwell test used a  $\frac{1}{16}$  inch steel ball with a 100 kilogram load. Brinell test used a 10 millimeter ball 3000 and 500 kilogram loads.

chanical difficulties in measurement. By the use of the spherical segment equation the depth  $t$  is calculated by formula  $t = \frac{D}{2} \sqrt{\frac{D^2 - d^2}{4}}$  where  $D$  is the diameter of the ball used in making the impression and  $d$  is the diameter of the impression thus made.

The conventional Brinell table is then made up on the assumption that the Brinell impression is a true spherical segment of the ball making the test.

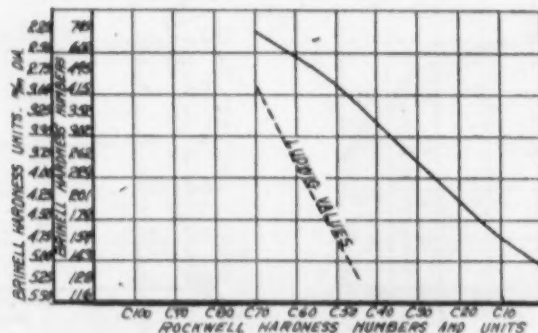


Fig. 26 Conversion chart showing the Ludwig and Brinell number relationship. Data taken from tests shown in Figs. 4-24. Rockwell test used 120-degree diamond cone with 150 kilogram load. Brinell test used 10 millimeter ball with a 3000 kilogram load.

This assumption is, however, not correct for two reasons. First, a deformation of the ball used in making the test. This deformation is greatest on the hardest metals due to least amount of support. Second, a recoverance of the metal under test, which is in proportion to the work applied, the work being greatest at the point of greatest depth and decreasing toward the rim of the impression.

An example to demonstrate this is here cited. A piece of 0.35 per cent carbon steel was Brinelled and the impression diameter was 4.00 millimeters. By the spherical segment formula the depth should be 0.42 millimeter. On actual and close measurement, the actual depth after the load had been released was 0.29 millimeter. This was then a loss of 0.13 millimeter in depth,

which was due in part to ball deformation and in part to recoverance of metal. If the Brinell number is calculated from actual depth 0.29 millimeter, the result is 329. The Brinell number calculated from the actual diameter 4.00 millimeters, is 228. It is also observed that various metals tested are subject to various degrees of recoverance. It is, therefore, logical to assume that various Brinell balls, due to a difference in composition and heat-treatment, may have different elastic deformations.

A realization of these conditions explains to a more or less extent the following: the reason that two metals of the same Brinell hardness have different machining qualities, and the reason the various depth reading attachments furnished for Brinell machines have failed to check Brinell read-

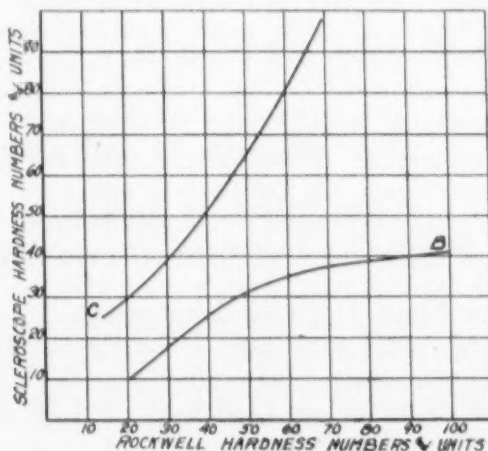


Fig. 27 Experimental test conversion chart of Rockwell test to scleroscope hardness numbers. Curve B, shows results obtained in testing common brass. Rockwell test used  $\frac{1}{16}$  inch steel ball with 100 kilogram load. Scleroscope model C. Curve C, shows results obtained from data in test shown in Figs. 4-24. Rockwell test used 120 degree diamond cone with 150 kilogram load. Model C and D averages from scleroscope tests.

ings obtained by diameter calculation and that the calculation of hardness by depth measurement brings in other properties of metal than Brinell by diameter which is usually accepted as a degree of the plasticity of the metal.

Bearing these conditions in mind, we see that with a depth reading hardness tester working on the impression principle we can compare depths in terms of Brinell hardness numbers by a theoretical conversion scale or by the existing conventional conversion scale. The theoretical conversion is merely a question of mathematics. The conventional conversion, on the other hand, cannot be applied mathematically as the conventional scale does not allow for a multitude of varieties of balls and materials. Therefore, the conventional conversion must be made by experimental test results.

#### *Scleroscope Test*

As the scleroscope hardness depends on the height of rebound of the hammer, and as the indentation made by the hammer on the steel is too small to measure by depth, and as the bounding edge of the indentation is not circular, mathematics can not be used to draw a relation between height of rebound and indentation measurements.

Therefore, in converting scleroscope hardness units to hardness units of any other system a theoretical conversion is not available, and any conversion must be made by experimental test results. It is found that metals of differ-

ent composition have an effect on the conversions, so that no one conversion chart can exactly apply to all metals. As the commercial methods of testing are conducted, however, a general conversion is commercially practical.

### Conversion of Rockwell Hardness Units to Brinell Numbers

There are two standard conditions of Rockwell tests:

1. The standard 1/16-inch diameter steel ball under 100 kilogram load.
2. The standard 120-degree diamond cone under 150 kilogram load.

There are many other combinations of ball sizes and loads which convertible both by theory and test need not be considered in this paper as they are special conditions and where used should be stated.

#### Conversion for Rockwell with 1/16 inch Steel Ball 100 Kilogram Load

The Brinnell hardness number formula is

$$1. \quad \text{BHN} = \frac{P}{\pi D t}, \text{ where } P = \text{Pressure in kilograms.}$$

$D = \text{Diameter of ball used in making impression.}$   
 $t = \text{Depth of impression thus made.}$

On the Rockwell tester two pressures are used causing two different depth impressions:

- $t_1$  due to minor load  $P = 10$  kilograms.
- $t_2$  due to increment of total load  $P = P_2 = 90$  kilograms.
- $t_1 + t_2 = t$ ; major or total load  $P = 100$  kilograms.

Further,  $D$  ball diameter = 1/16 inch = 1.58 millimeters.

Substituting in equation 1, we have:

$$2. \quad \text{BHN} = \frac{P_1 + P_2}{\pi D (t_1 + t_2)} = \frac{P}{\pi D (t_1 + t_2)}$$

Now, unlike the relation between pressure and diameter of impression, the ratio of the pressure to the depth of the impression is proportional or

$$\frac{P_1}{P_2} = \frac{t_1}{t_2} \text{ solving for } t_1 = \frac{P_1 t_2}{P_2}$$

Substituting in equation 2,

$$3. \quad \text{BHN} = \frac{P}{\pi D \left[ \frac{P_1 t_2}{P_2} + t_2 \right]} = \frac{P}{\pi D t_2 \left[ \frac{P_1}{P_2} + 1 \right]}$$

Substituting the known values in equation 3, we have:

$$4. \quad \text{BHN} = \frac{18.2}{t_2}$$

Now the Rockwell unit is 0.002 millimeters; and the hardness number is the difference between the measurement of depth and an arbitrary figure of 130\*.

$$t_2 = (130 - R) \quad 0.002 = 0.26 - .002 R$$

Substituting in equation 4, we have:

$$5. \quad \text{BHN} = \frac{18.2}{(130 - R) \cdot 0.002} = \frac{9100}{130 - R}$$

\*See preceding text as regards the Figure 130.



The dotted curve on Fig. 25 is the theoretical conversion Rockwell to Brinell by the above equation under the above conditions. This varies considerably from the solid line curve which is the experimental test conversion curve. The reason for this is the ball deformation and test metal recoverance mentioned before.

The solid line is for all commercial practice satisfied by the formula.

$$\text{BHN} = \frac{6870}{130 - R}$$

*Conversion of the 120 Degree Diamond Point 150 Kilogram Load into Brinell*

The cone test proposed by Ludwig calculated the hardness numerals from the pressure divided by the area of the projected impression. The area of the impression was figured by the measurement of depth of indentation  $t$ .

$$\text{LHN} = \frac{P}{\pi r^2}$$

Where  $P$  was pressure in kilograms and  
 $r = t \div \tan$  of half of the cone angle.

The relation of load depth and impressions of a cone bear no relationship to that of a sphere, so that no theoretical conversion can exist.

On Fig. 26 the dotted curve shows the Ludwig Rockwell conversion, the Brinell number in this case may be used as Ludwig numbers. On the same chart the solid curve represents the experimental test conversion curve for the Rockwell numbers to the conventional Brinell system. The solid line for commercial use is satisfied by the formula.

$$\text{Brinell diameter in millimeters} = .0465 (100 - R) + .55$$

*Experimental Test Conversion of Rockwell With 1/16 inch Steel Ball 100 Kilogram Load to Scleroscope Hardness Numbers*

This work was done on nonferrous metals. The solid line B, Fig. 27, shows the average of results obtained from these tests.

*Experimental Test Conversion of Rockwell With 120 Degree Diamond Cone and 150 Kilogram Load*

This work was done on the steels mentioned in the body of this paper. The solid line C, Fig. 27, shows the average of results obtained from these tests.

The curve C is commercially satisfied by the equation:

$$S = \frac{R^2}{60} + 23$$

**Conversion Tables from Tests**

Conversion Table I for the Rockwell C scale was derived as follows: The Rockwell, scleroscope and Brinell values were obtained from the tests shown by Figs. 4-24. The column headed "Ultimate pounds per square inch" is the conventional table as figured from the Brinell hardness number by the formula.

$$\text{Pounds per square inch} = \text{BHN} \times 494$$

The Rockwell tester may be used to commercially read in scleroscope numbers by using a different zero point on the C scale as a starting point for tests.

When Scleroscope Specifications call for	Start Tests on Rockwell Tester at (and read on C scale as Scleroscope Number)
95—105	C 30
90—100	C 26
85— 95	C 24
80— 90	C 22
75— 85	C 20
70— 80	C 18
65— 75	C 17
60— 70	C 15
55— 65	C 13
50— 60	C 11
45— 55	C 10
30— 50	C 9
25— 35	C 10
20— 30	C 11
15— 25	C 13

Conversion Table II for the Rockwell B scale was derived from tests 6, 4 and 2 number hard common brass, annealed in the same manner as the steel samples mentioned in this paper were drawn. The Rockwell, scleroscope and Brinell values are the average of these tests. The Brinell indentations were made at 500 kilograms pressure using a 10 millimeter ball. The column of millimeter diameters under 3000 kilograms is added to show the equivalent diameter at 3000 kilograms. The scleroscope values were obtained on the Model C scleroscope chucked on the standard frame chuck. The brass was in all cases 0.077 inch gauge, smooth and bright of surface.

CONVERSION TABLE I

Rockwell C scale 120 degree Cone 150 kilogram Load	Scleroscope Average of Models C & D Scleroscopes	Brinell millimeter diam. 10 millimeter ball 3000 kilogram Load	Brinell Numbers	Ultimate Strength pounds per square inch
75	..	.....	...	.....
74	..	.....	...	.....
73	..	.....	...	.....
72	..	.....	...	.....
71	..	.....	...	.....
70	98	2.25	745	366,600
69	96	2.255	725	357,000
68	94	2.30	712	350,600
67	92	2.35	682	335,700
66	90	2.375	668	327,000
65	88	2.40	654	323,000
64	87	2.45	627	3008,40
63	85	2.475	614	390,000
62	83	2.50	602	26,5000
61	82	2.525	590	290,000
60	80	2.55	578	284,300
59	78	2.60	555	273,300
58	77	2.625	545	268,000
57	75	2.65	534	263,000
56	74	2.70	514	254,000
55	72	2.725	504	248,600
54	71	2.75	495	243,800
53	69	2.80	478	235,100

(Continued)

CONVERSION TABLE I (Continued)

Rockwell C scale 120 degree Cone 150 kilogram Load	Scleroscope Average of Models C & D Scleroscopes	Brinell millimeter diam. 10 millimeter ball 3000 kilogram Load	Brinell Numbers	Ultimate Strength pounds per square inch
52	67	2.85	461	226,400
51	66	2.872	452	222,300
50	65	2.90	444	218,700
49	64	2.95	429	211,100
48	63	3.00	415	203,800
47	61	3.05	401	197,200
46	59	3.10	388	190,900
45	57	3.15	375	184,600
44	56	3.20	363	178,700
43	54	3.25	352	173,300
42	53	3.275	346	170,100
41	52	3.30	341	167,900
40	50	3.35	331	162,600
39	49	3.40	321	157,800
38	48	3.45	311	153,100
37	47	3.50	302	148,600
36	45	3.55	293	144,300
35	44	3.60	285	140,100
34	43	3.65	277	136,200
33	42	3.70	269	132,400
32	41	3.75	262	128,800
31	40	3.775	258	126,700
30	39	3.80	255	125,300
29	38	3.85	248	121,900
28	37	3.90	241	118,700
27	36	3.95	235	115,500
26	35	4.00	229	112,700
25	34	4.05	223	109,700
24	33	4.10	217	106,900
23	32	4.15	212	104,200
22	31	4.20	207	101,600
21	30	4.25	201	99,000
20	30	4.30	197	96,800
19	29	4.35	192	94,400
18	28	4.40	187	92,200
17	27	4.425	185	91,100
16	27	4.45	183	90,000
15	26	4.50	179	87,900
14	25	4.55	174	85,800
13	24	4.60	170	83,900
12	23	4.65	167	82,100
11	23	4.675	165	81,800
10	22	4.70	163	80,100
9	..	4.75	159	78,300
8	..	4.80	156	76,600
7	..	4.825	154	75,000
6	..	4.85	152	74,700
5	..	4.90	149	73,300
4	..	4.93	147	71,900
3	..	4.95	146	71,700
2	..	5.00	143	70,200
1	..	5.03	141	68,900
0	..	5.05	140	68,700



CONVERSION TABLE II

Rockwell B scale	Scleroscope Model C	Brinell Millimeter diam. 10 Millimeter ball		Brinell Numbers
		3000 kilograms	500 kilograms	
100	41	4.00	....	229
99	..	4.05	....	223
98	..	4.08	....	219
97	..	4.13	....	214
96	..	4.17	....	210
95	..	4.22	....	205
94	..	4.27	....	200
93	..	4.30	....	197
92	..	4.35	....	192
91	..	4.40	....	187
90	40	4.45	....	183
89	..	4.50	....	179
88	..	4.53	....	176
87	..	4.57	....	172
86	..	4.62	....	169
85	..	4.67	....	165
84	..	4.72	....	162
83	39	4.75	....	159
82	..	4.80	....	156
81	..	4.84	....	152
80	..	4.87	2.05	151
79	..	4.92	....	148
78	..	4.97	....	145
77	..	5.02	2.10	142
76	..	5.05	....	140
75	38	5.08	....	138
74	..	5.12	2.15	136
73	..	5.16	....	133
72	..	5.20	....	131
71	..	5.25	2.20	128
70	..	5.30	....	126
69	..	5.33	2.25	124
68	37	5.37	....	122
67	..	5.41	....	120
66	..	5.45	2.30	118
65	..	5.48	....	117
64	36	5.52	....	115
63	..	5.56	2.35	114
62	..	5.59	....	111
61	..	5.64	2.40	109
60	35	5.67	....	108
59	..	5.71	....	107
58	..	5.75	....	105
57	34	5.78	2.45	104
56	..	5.82	....	102
55	33	5.85	....	101
54	..	5.89	2.50	99
53	32	5.92	....	98
52	..	5.97	....	97
51	..	6.00	2.55	96
50	31	....	....	95
49	..	....	....	94
48	30	....	2.60	92
47	..	....	....	90
46	29	....	2.65	89
45	..	....	....	88
44	28	....	....	87
43	27	....	2.70	86
42	..	....	....	85
41	26	....	....	84

(Continued)

CONVERSION TABLE II (Continued)

Rockwell B scale	Scleroscope Model C	Brinell Millimeter diam. 10 Millimeter ball		Brinell Numbers
		3000 kilograms	500 kilograms	
40	25	....	2.75	83
39	..	....	....	82
38	24	....	....	81
37	23	....	....	..
36	22	....	2.80	80
35	..	....	....	79
34	21	....	....	78
33	20	....	2.85	77
32	19	....	....	76
31	..	....	....	75
30	18	....	2.90	74
29	17	....	....	..
28	16	....	....	73
27	15	....	2.95	72
26	..	....	....	71
25	14	....	....	70
24	13	....	....	..
23	12	....	3.00	69
22	..	....	....	68
21	11	....	....	..
20	10	....	2.05	67
19	..	....	....	66
18	..	....	3.10	65
17	..	....	....	64
16	..	....	3.15	63
15	..	....	....	62
14	..	....	3.20	61
13	..	....	....	60
12	..	....	3.25	59
11	..	....	....	58
10	..	....	3.30	57
9	..	....	....	56
8	..	....	3.35	55
7	..	....	....	54
6	..	....	3.40	53
5	..	....	3.45	52
4	..	....	....	51
3	..	....	....	..
2	..	....	3.50	50
1	..	....	....	..
0	..	....	3.55	49

The writer wishes to thank the following for their assistance in the use of testing apparatus and materials:  
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Mr. A. H. D'Arcambal Metallurgist of Pratt & Whitney Co., of Hartford, Conn.

The information conveyed in Technologic Paper No. 11 of the Bureau of Standards has been used as a basis for conversion data.

THE MANUFACTURE AND PROPERTIES OF WROUGHT IRON  
By James P. Baldwin

THERE are two principal methods which may be used for the manufacture of wrought iron, the first being a direct process by reduction from the ore, and the second, and indirect process based on the refining of pig iron. The latter is by far the more important, but the first, since it has an historical value, will be briefly described.

The production of simple malleable iron direct from ore began among the ancients and was accomplished by heating iron ore in the presence of a reducing agent, such as charcoal, in an open fire. As time passed these iron masters went to the hill top where they could take advantage of the strong winds to produce results in shorter time. The use of chimneys, followed by short stacks with artificial blast, still further increased their output. Finally in Catalonia, a province of Northern Spain, the Catalan forge was developed which had no essential difference from the cruder appliances used except that by means of a blower called a "trompe", an air blast of 1 1-2 to 2 pounds per square inch was developed and production amounted to about 300 pounds of iron in six hours. The American Bloomery followed and altho it was restricted to the use of magnetic iron ore finely divided, it produced larger quantities than the Catalan Forge; its principle was the same and varied only in the fact that the sides of the hearth were water cooled and that pressure was produced by means of steam or by a water-wheel. Attempts to produce wrought iron direct from ore commercially have been many, but without any permanent success so that today the indirect pig-boiling or puddling process is the prevailing method. The pig iron used is known as "forge iron" or "mill iron" and while different mills vary widely in their specifications for their pig iron, the following represents average practice:

Carbon.....	not specified
Phosphorus.....	less than 1.00 per cent
Sulphur.....	not over 0.1 per cent
Silicon.....	0.75 to 1.25 per cent
Manganese.....	0.50 to 1.00 per cent

The presence of some silicon is necessary to the proper working of the puddling process but excessive amounts should be avoided because of the unnecessarily large amount of iron that will be slagged off. Too high or too low silicon results in longer time per heat. Some phosphorus is an advantage as it tends to increase the yield and prevents the slag from getting too thick at the end of the operation, while on the other hand too much of this element leads to a waste of iron, and makes it almost impossible to produce a good structured iron. Sulphur should be low permitting the removal of most of it before the burning of the carbon, thereby prolonging fluidity and thus aiding the removal of phosphorus and sulphur.

The puddling furnace has changed but little in its essentials since the invention of the process of Joseph Hall in 1830. It is a single-bedded reverberatory furnace, lined externally with plates bound together with rods and provided with stoke holes for firing when coal is the fuel and a working door, or sometimes two, one on either side of the

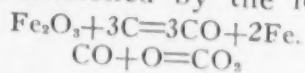
A paper presented before the Hartford Chapter.



hearth. It is lined internally and roofed with fire-brick. The hearth is oblong in form and the sides and bottom are covered with a layer of nearly pure oxide of iron called "fettle." The size of the furnace depends on the ability of the puddler to reach the different parts of the furnace hearth and exert effective force therein. Its capacity varies from 500 to 1500 pounds per heat, the usual size being from 900 to 1200 pounds. The lining of the hearth, or bottom, may be made from roll scale, iron ore, puddle cinder, or a combination of these in various proportions, practice differing in the various works. The resulting fettle is roughly classified under three heads, fusible, moderately fusible and infusible. Generally speaking the infusible kinds are more costly and contain fewer impurities. In the fusible class we have as representative the slag taken out of the puddle ball at the squeezer, which is somewhat purer than the slag which runs from the furnace during the "boil". "Bull dog" or calcined tap cinder is a type of the partly fusible fettle. Infusible fettle is composed of ferric or magnetic oxide of iron.

In commencing work with a furnace the first object is to get a good firm bottom. This is done by covering the cast iron plates which form the bottom with refractory fettle and roll scale and then lighting the fire, getting enough heat to cause good coherence of the mass. Scrap iron is sometimes added, raised to a welding heat and worked around the various parts of the hearth to aid the production of a good sound mass. The bottom must be kept in good order so that when working the furnace the melting pig does not come in contact with the cast iron plates which would be eaten through. After the bottom is made, low walls from the same material are developed in order to form a basin for the working of the metal.

The pig iron is hand-charged through the working doors of the furnace and vigorously heated for the first half to three-quarters of an hour in order to melt it down rapidly. During this period most of the silicon and manganese are removed as well as a considerable quantity of phosphorus and sulphur. This is followed by charging roll scale or iron ore to produce a basic slag and the fire is damped and sometimes even a tin or so of water is thrown on the bath to bring down the temperature. This is done for the purpose of bringing the temperature to a point where phosphorus and sulphur will be removed before the carbon. As is well known, the purer the iron the higher its melting point which means that if the carbon were burned out ahead of the other impurities, a pasty mass of metal would result which would be high in phosphorus and sulphur, a result highly undesirable. When the carbon begins to oxidize, light blue flames of burning carbon monoxide break through the slag, occasioned by the following reactions:



Unless the slag is very basic at this point the carbon monoxide may reduce the phosphorus and sulphur causing them to go back into the metal. Some mills practice the use of soda ash (commercial sodium carbonate) to render the slag more basic and fluid. As this formation of CO progresses, the metal begins to boil, the mass swells and about half of the slag content of the furnace flows out of the cinder hole into a slag buggy. The boiling lasts 20 to 30 minutes and while it is in progress the puddler and his helper rabble the contents of the furnace with hoe-like bars to keep the bath uniform, to keep the iron from settling.

on the bottom and to bring the entire mass of metal in contact with the slag for the removal of impurities. Toward the end of the boiling, which indicates the removal of nearly all the carbon, the metal "comes to nature" and points of solid metal project up thru the slag and collect on the bottom. This must be remedied in order to prevent the loss of metal, chilling of iron on the bottom and unevenness in composition. When the entire mass has come to nature the puddlers begin to work the metal into balls of about 150 to 175 pounds in weight, using their rabbles and placing the balls near the bridge wall to keep them hot and the slag fluid until they are removed. When the metal is entirely "balled" the balls are removed, one at a time, and dripping with slag, are carried with wide-jawed, long-handled tongs suspended from a mono-rail, to the squeezer.

The squeezer consists of an outside-corrugated, rotating cylinder set off-center inside of another stationary cylinder, inside-corrugated and having an opening in its side from top to bottom for the entrance and removal of the puddle ball. The result of the action of the squeezer is to knead and elongate the puddle ball as it is carried around by the rotating cylinder, its form when leaving the squeezer being that of a rough cylinder of about 14 inches to 18 inches in diameter and from 24 inches to 36 inches long. This is passed through puddle rolls, coming through as "muck bar", having a cross section of about  $\frac{5}{8}$ -inch x 4-inch, though this varies according to the practice of each individual mill and the purpose for which the metal is intended.

The muck iron passes on to a roll table which carries it to the shears where it is cut into lengths of about  $2\frac{1}{2}$  to 3 feet. It is then sprayed with water to cool it, piled by laying succeeding layers at a right angle to the layer immediately beneath, tied with wire, raised to a welding heat and rolled again, making what is known as single-refined wrought iron. If this product is treated to the above operations of piling, tying, heating and rolling a second time, it is known as double refined iron. The time required for a complete cycle of the above operations is from  $1\frac{3}{4}$  to  $2\frac{1}{4}$  hours.

In addition to the above method, a large tonnage of so-called wrought iron is produced by breaking up iron pipe by means of drop hammers, mixing other iron scrap with it, piling it, raising it to a welding heat and rolling it. This results in an inferior product but is used for the less important products.

The fuel used is usually bituminous coal which burns with a long flame. Some plants have been using powdered coal with marked success while others have had good results from oil fuel. The loss of heat from the waste gases is often prevented by placing a boiler over the puddle furnace and conducting the hot gases through it before passing them to the stack.

Losses incurred in the puddling process due to oxidation of impurities and some slagging off of iron, run from 4 to 8 per cent of the weight of the metal charged. The amount of slag produced varies directly as the silicon content of the charge and runs from  $\frac{1}{4}$  to  $\frac{1}{2}$  of the weight of the metal placed in the furnace.

Many efforts have been made to puddle mechanically but the furnaces designed with this end in view have not been a success and hand puddling continues, and probably will continue in the future, to be the usual practice. One advantage of the puddling process is the

ability to deal with widely varying irons but each individual mill should adhere very closely to the use of one kind of iron because a change in its composition causes the metal to work differently, causing confusion among the puddlers until they become accustomed to the working of the new iron.

The chemical composition of bar varies widely depending upon the use to which it is to be put. If it is to be used for crucible steel, its composition would be about as follows:

Carbon.....	0.05—0.15 per cent
Phosphorus.....	0.010—0.020 per cent
Sulphur.....	0.010—0.020 per cent
Manganese.....	0.05—0.10 per cent
Silicon.....	0.10—0.30 per cent

If the muck bar is to be piled and rolled into refined iron, the resulting product may contain about 0.020 per cent to 0.030 per cent sulphur and phosphorus between 0.075 per cent and 0.200 per cent manganese and carbon being about as above. Finished wrought iron, double-refined, has a composition about as below; although different from steel, the character of wrought iron is not easily predicted from its chemical analysis:

Carbon.....	0.05—0.10 per cent
Phosphorus.....	0.10—0.30 per cent
Sulphur.....	0.020—0.040 per cent
Manganese.....	0.02—0.10 per cent

It should be noted that the practice of puddling varies rather widely and this has a direct influence on the composition of the final product; the above figures are, therefore, only average.

Concerning the physical properties of wrought iron, it may be interesting to note the following figures taken from Turner's "Metallurgy of Iron", which not only give one an idea of the effect of multiple refining on the strength of wrought iron but also to hold out a warning that it is possible to carry the refining too far:

	Tensile Strength Pounds per square inch
Original puddle bar.....	44,000
2nd working.....	53,000
3rd working.....	60,000
4th working.....	60,000
5th working.....	57,000
6th working.....	62,000
7th working.....	60,000
8th working.....	57,000
9th working.....	57,000
10th working.....	54,000
11th working.....	52,000
12th working.....	44,000

As a general rule it is of little advantage to carry the refining beyond "double-refined" iron. The tensile strength of wrought iron varies from 36,000 to 60,000 pounds per square inch, depending on its composition, its refining size of test piece, etc. The elastic limit runs from 24,000 to 32,000 pounds per square inch. Per cent elongation varies from 15 to 25 per cent, while the reduction area usually lies between 40 and 50 per cent for the better grades. The latter quantity is a safe



guide to the probable quality of the iron as poor iron with equal strength will often show only 30 per cent reduction of area.

If a longitudinal section of a piece of wrought iron be examined under the microscope it will be found that it consists of grains of commercial ferrite, carbonless iron, containing phosphorus, sulphur, etc., as impurities, crossed by irregular dark bands of slag, elongated in the direction of rolling. A transverse section shows these particles of slag as rounded spots, being cross sections of the bands in the longitudinal section. The ferrite is of the same appearance in both longitudinal and transverse sections and explodes the theory that wrought iron has a "fibrous" structure. The slag contained in the metal is composed of both ferrous and ferric oxides, silica, oxide of manganese and phosphorus pentoxide.

The resistance of wrought iron to corrosion is remarkable: at Delhi, India, there is a column of this material weighing more than six tons which is about fifteen hundred years old.

Wrought iron has a corded appearance when nicked and bent to destruction, due to the bands of slag contained in it. The metal welds nicely although close control of the temperature is necessary with the better grades. Its superiority over steel for withstanding alternating bending stresses is well established.

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## LOCAL HARDENING OF EXTRUDING DIES

By Edwin H. Barker

THE designer of special tools for many types of automatic machines, finds that his work is daily becoming more complex. He must adapt his tools to the machine available for the job and he must make them as nearly fool-proof as possible, and, above all, he must make them turn out perfect work twice as fast, as would have been considered reasonable a few years ago. In many cases the machines available have been hastily designed, and have such a narrow field of use, that much faulty design persists, through lack of sufficient competition among the manufacturers to stimulate improvement. Given these conditions, the tool designer must call to his aid a wide range of tool steels, and the most careful and accurate methods of heat treatment available, together with highly specialized methods of application designed to meet the necessities of the various types of tools required.

Fig. 1-a shows a set of tools for a semi-automatic cap press, designed for the manufacture, in one operation, of caps for collapsible tubes, the blanks being fed to the die by a simple form of tube and finger mechanism. This die has been broken in half to show the construction, the blanks and finished work as it comes from the press being shown to the left of the tools.

The construction of this press is such that the high pressures necessary to form the threads and decorations of the cap, and limited by the small amount of support the die has where it is held in the counter-bored die slide of the press, often caused the dies to burst when operating at high speed. A die broken in this manner is shown in Fig 1-b.

It is necessary to keep a high polish on these tools, both for the appearance of the product, and for the proper operation of the tools, therefore a steel must be used which is hard, close-grained, capable of taking and retaining a high polish against the abrasive action of the flowing metal, and yet not be too brittle to withstand the pressure necessary to hold the lower gate in contact with the die against the action of the punch. Obviously, as it is not easily possible to increase either the thickness or diameter of these dies, owing to the light construction and crowding of the parts of the press, the solution of this problem lies in the local hardening of those surfaces exposed to wear, while retaining the toughness of the softer steel in the rest of the die. The methods of local hardening which are to be described, not only meet this requirement, but enable us to more thoroughly harden the internal surfaces of dies having very small apertures.

Quenching jets for obtaining these results are shown in Fig 1-c, one type for dies where all the wearing surfaces are in the bore, and the other where a portion of the face of the die as well as the bore is exposed to abrasive action. The holes can be clearly seen in the photograph. Fig. 1-d shows three types of jets used in the hardening of extruding dies for the manufacture of collapsible tubes, dispensing bottle tops, etc. It will be noticed that the one to the right has a central opening closed by a screw, which may be removed to permit the addition of a jet for the deep hardening of dies for tubes with long conical necks. Special attention is directed to the jet on the left, which is used in quenching closed end dies where only the bottom and walls must be glass hard, and the diameter of the opening is not over 0.250 inch. In quenching the heated die is inverted over the jet

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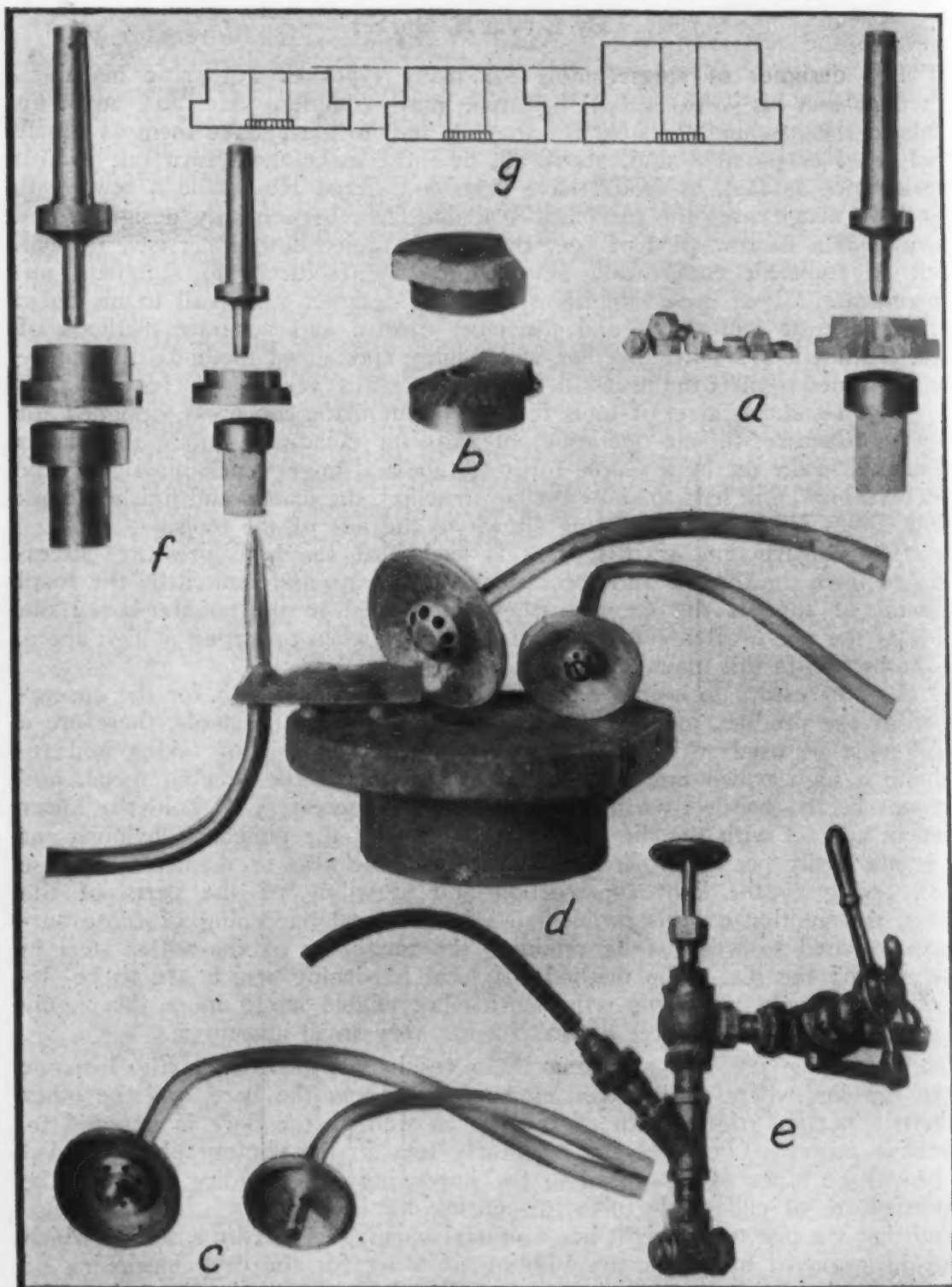


Fig. 1—*a*. Shows a set of tools for a semi-automatic cap press. The die has been broken to show its construction. *b*. A die broken as the result of improper support to withstand the excessive pressures needed to form the threads and decorations of the cap. *c* and *d*. Shows quenching jets for hardening dies. *e*. Shows the quick acting control valve. *f*. Shows a comparison of the dies for a large and a small sized press. *g*. Shows a comparison of the shoulder and body of large and small dies.



and the full pressure applied as quickly as possible. The water is driven out along the spiral grooves and the centrifugal action thus set up prevents the formation of steam or air pockets in the die. These jets are supplied with water at about 50 degrees Fahr., under pressure of 60 pounds per square inch, and are controlled by a quick-acting lever gate-valve which will be described later. The form of shield shown, has proven very satisfactory; the results showing a gradual tempering of the die from the almost glass hard center out towards the soft exterior, which provides sufficient stiffness to prevent distortion, with toughness necessary to prevent bursting. The construction of these jets is very simple, and the forms required to quench special shapes of dies can be quickly made. The supply tube is made of copper, the shield is hammered or pressed from 1/16-inch sheet copper, and the head is turned from a brass bar of suitable diameter, drilled and counter-bored to receive the end of the supply tube, and the whole fixture is assembled and securely soldered in place. All jets designed for quenching dies of circular section, should have the jet-holes bored tangentially, as this will set up centrifugal action and thus insure the closest possible contact of the water with the steel.

The control valve used, is so designed that all sizes and types of jets are attached interchangeably. It has several unique features which have been developed to eliminate small leaks, which seems to be the tendency of nearly all quick acting valves.

Fig. 1-e shows the control valve. The water enters through the quick acting lever gate-valve, passing through the angle valve, which is used to reduce pressure when necessary, down to the Y on the side outlet, to which is attached the rubber tube carrying the jet. The lower opening of this Y terminates in a bronze ball angle check valve. The whole fixture is set on a slight angle, so that the ball of the check valve tends to fall away from its seat. This allows all small leakage, as well as the water in the jet, rubber tube and fittings to drip away. When, however, the full force of the water is turned on this ball is forced against its seat, and the full stream is diverted through the branch of the Y to the jet. This device has entirely overcome the formation of soft spots in dies, caused by stray drops of water falling on the work ahead of the full supply necessary to efficient quenching.

If we may return to the consideration of the cap dies for a moment, you will see in Fig 1-f a comparison of the dies for a larger size press, with the small size. The builders of this machine, at our request, increased the proportionate thickness of the die slide, making possible the use of the die shown. The increased life of dies of this larger size more than justifies this change of design. A die similar to the one shown has been in continuous service for several months, and has just been condemned with a record of 1,200,000 pieces. It is obvious that the larger mass of this die, parallel to the greatest pressure exerted against it, makes possible the use of a harder closer-grained steel than we have been able to use successfully in the smaller size, without running the risk of bursting under the pressure developed at the high speed of production maintained. The results with this press were so encouraging that we rebuilt several of our small machines to take our medium standard size dies. This change entailed a considerable outlay of money.

In Fig. 1-g it will be noted that the designer of the large size die failed to increase the shoulder in proportion, even to the small size die, while we,

(Continued bottom Page 1042)

## Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

The answer to Question No. 24 published in the July TRANSACTIONS contained the tabulated analysis of the steel which was used in carrying out these experiments. Our attention has been called to the fact that the silicon content is in error.

Complete analysis should be as follows:

	Per Cent
Carbon	0.15 to 0.20
Manganese	0.35 to 0.65
Phosphorus, below	0.040
Sulphur, below	0.040
Silicon	0.05 to 0.10

(Continued from Page 1041)

profiting by many costly failures, have materially cut down the body of the die in proportion to the shoulder. This size die is made of the same steel as the larger size, and shows at least equal efficiency. The heating of all of these tools is accomplished in a special type electric furnace. This furnace is equipped with a pyrometer system which indicates when the die which is being heated passes through the critical range of temperature. Very satisfactory and uniform results have been obtained with this heat treating equipment.

In conclusion, a word regarding methods of keeping records of manufacture and production of tools, and the condition and proportionate production of the presses. The tool symbol, serial number, bar number of the steel, and initials of the toolmaker are stamped on the tool itself; all other details being added to the record card as the work is completed. The tool is then listed as ready for production. A daily record of production of each press is kept, showing the comparative performance of each machine; as well as the tool production, which is transferred to the tool record at the end of each period of continuous use. The daily press records serve to show when a machine is falling below its proper production, and inspection as to the cause is followed by the issue of a damage report covering the repairs necessary. The analysis of these reports and records has made possible the separation of failures due to faulty design from failures due to lack of proper alignment in the presses in a very satisfactory manner.

## The Question Box

A Column Devoted to the Asking, Answering and Discussing of  
Practical Questions in Heat Treatment—Members Submitting  
Answers and Discussions Are Requested to Refer to  
Serial Numbers of Questions.

### NEW QUESTIONS

QUESTION NO. 37. *What is the role of vanadium in steel?*

QUESTION NO. 38. *What regulations are recommended to reduce the fire hazard of quenching tanks?*

QUESTION NO. 39. *What happens to a piece of steel when it is tempered or drawn back after quenching from above the upper critical point?*

QUESTION NO. 40. *What is the influence of a low percentage copper content in steel?*

### OLD QUESTIONS AND ANSWERS

QUESTION NO. 8. *What is the effect of high and low silicon in tool steel?*

QUESTION NO. 12. *How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?*

ANSWER. When a casting such as an automobile cylinder block cools down in its mold from the molten condition, cooling strains are set up within the casting due to the shrinkage of the metal during solidification, also frequently there is a chilling effect due to the contact of the metal with the mold walls, this causing an increased hardness of the surface metal which is usually difficult to machine. It is the practice of many automobile companies to accumulate motor block castings and store them in the open for suitable periods of time. This storage in the open permits of rusting and this rusting or ageing relieves the surface hardness as well as the casting strains, so that when a cylinder block is machined and the bores ground, it will not change its shape. Weathering castings is a long procedure requiring from 1 to 2 years and in many cases it is impossible for manufacturers to accumulate weathered castings in sufficient quantities to meet their production demands, therefore the expedient of annealing castings to accomplish the same effects have been used extensively. Numerous investigations have been conducted, first to determine the correct time and temperature required for annealing gray iron castings; second, to determine the effect of annealing on the physical properties; third, to determine the effect of annealing and quenching on the physical properties. It has been shown in several investigations that a temperature of 1150 degrees Fahr. is suitable for annealing to relieve casting strains. Annealing at lower temperatures than this apparently does not materially reduce the strength of the casting nor its



hardness. In order to increase the machinability it has been found that temperatures ranging from 1450 degrees to 1550 degrees Fahr. have proved sufficient although annealing at these temperatures seems to reduce the strength of the casting. The time for the satisfactory annealing of castings seems to be approximately one hour as compared with many months of weathering. The rapidity of cooling from the annealing temperature apparently has little effect.

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*QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree*

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*QUESTION NO. 26. Does the presence of pearlite in the decarburized zone of a malleable iron casting effect the resistance of this casting to shocks?*

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*QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?*

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*QUESTION NO. 30. How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?*

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*QUESTION NO 31. What is the effect of oxidizing gases at low pressure on heated iron?*

ANSWER. By Prof. H. C. H. Carpenter and Miss C. F. Elam in a paper presented before the annual meeting of the Iron and Steel Institute, May 1922. This paper was entitled the "Effect of Oxidizing Gases at Low Pressures on Heated Iron." The following is a reprint of this paper:

The experiments to be described in this paper originated in the following way. The authors were experimenting with the vacuum etching of copper which was heated in a silica tube, at temperatures in the neighborhood of 1000 degrees Cent. The metal evolved a considerable volume of gas which, if allowed to remain in the tube, caused it to blister. If, however, the gas were pumped off as soon as it was evolved and the vacuum maintained, the copper remained bright and quite free from oxidation. Under these conditions the structure of the copper grains was rendered manifest by what may be termed a heat etch. It so happened that on one occasion Armco iron was placed in the tube with the copper, although not in contact with it. The tube was then evacuated and heated to about 1000 degrees Cent. The gas evolved from the two metals was not pumped off, but allowed to accumulate in the tube. At the conclusion of the experiment, when the metals were withdrawn from the tube, it was found that each of them had altered considerably in appearance. On the one hand, the copper was found to have become coated with a layer of blue cuprous oxide, which in some places covered the metal completely, whereas in others it took the form of six-pointed stars deposited on the metal. On the other hand, the iron was distinctly lustrous, if rather dark, and appeared to be very deeply etched. Both specimens had been originally polished and sufficiently etched to show the outline of the crystal grains.

An experiment was then made by heating the iron itself in the absence

of copper, and tests were made with Armco iron, electrolytic iron, and Swedish iron. In each case a considerable volume of gas was evolved, but no etching effects were produced and the iron appeared to be slightly oxidized. The characteristic etching effect observed in the previous experiment therefore was evidently due to something evolved from the copper.

A series of experiments was then instituted to study the progress and characteristic features of the etch produced on the iron when heated with copper. In all these cases the metals were separated from one another in the tube. The structure of the iron as revealed under the microscope was found to depend both on the period of heating and the temperature. After short periods, such, for instance, as half an hour, at 1000 degrees Cent., the surface was found to be covered with small, somewhat irregular facets, whose orientation was constant on any one crystal but differed as a rule on passing from one crystal to another. Fig. 1 shows the structure at 300 diameters of the surface of the copper. This is hardly etched at all, although evidences of twin crystals are manifest. In the center is a blue star of cuprous oxide of very characteristic appearance, and deposits of this constituent are also visible in other parts of the field shown. Fig. 2 shows at 300 diameters the appearance of the surface of the iron after the above treatment. Portions of three grains are visible. On each of them will be observed characteristic facets which are constant in direction on any given crystal, but vary from one crystal to another. There are also decided differences of level between the tops of the facets of the adjacent crystals. Steeply sloping surfaces connect one grain with another, and these slope to different extents. Between one crystal and another the etching is so deep as to produce what may be called a valley.

The differences of level on passing from one grain to another became still more marked as the heating was carried further. The individual facets then became larger and more regular, but the surface was rendered more uneven. Fig. 3 shows at 600 diameters the structure of Armco iron after the more prolonged etching. Regular brick-like facets are visible in the center of the field. The dark area bounding these on the right is a sloping boundary, while the facets beyond are out of focus owing to the difference of level. Fig. 4 represents at 300 diameters the structure of two adjacent grains of electrolytic iron which are much larger than those of Armco iron, and are both approximately in focus. The facets in the upper half of the field strongly suggest an orientation parallel to the cube face, whereas those in the lower half represent a section of a crystal cut obliquely. Not only were the crystals of electrolytic iron larger than those of the Armco iron, but also the facets themselves.

On heating for a longer period, say for two hours, the surface became still more uneven and was found to be covered with perfectly regular squares, rectangles, and triangles, together with other figures of less regular shape. Fig. 5 at 600 diameters is a typical example of the structures thus obtained. In the former the rectangle etch figures predominate and in the latter the triangle. In these cases, owing to the very deep etch, only certain parts of the field can be obtained in focus at any given time. It was observed that the size and general form of the figures varied somewhat in different experiments owing, doubtless, to slight differences in pressure, and to variations in the composition of the gases evolved from both metals. Occasionally very minute etched figures were obtained, such as are illustrated in Fig. 6, at a magnification of 600 diameters, which represents part of one crystal in which

the etched figures appear as minute squares and rectangles. Substantially the whole of this field is in focus. The three or four irregularly shaped figures observed are due to slight porosities in the iron.

It remains now to consider what the etched figures really represent. The authors' first idea was that the structures observed were those of the etched iron, more particularly as the form of the figures agreed very well with what is known as to the crystal form of gamma and alpha iron. It very soon became evident, however, that the hypothesis was not correct in this form. It was found that, under certain conditions, small black shining crystals were formed on the surface of the iron, in addition to the etched figures described above. It was thought that these might be an oxide, and in removing some with a penknife in order to test it with a magnet, it was noticed that the "etch" layer could also be removed, revealing unaltered iron underneath. It appeared therefore that the characteristic etch figures were due to an oxidation of the iron during heating, and that accordingly they must be ascribed to an oxide and not to the metal. General support to this view was given by the fact that the copper itself was, as has been mentioned, also oxidized, the surface in certain places being almost completely covered with the characteristic blue cuprous oxide.

Further experiments were then carried out to determine what relation the structure of the oxide bore to that of the iron. It was noticed that if the specimen were heated to 1000 degrees Cent. several times, there was no change in the shape or size of the characteristic etch figures, although it is obvious that on every occasion a change in the crystal form of the iron itself must have taken place on passing through the  $Ac_3$  inversion and back again through  $Ar_3$ . In other words, it is clear that the alpha to gamma and gamma to alpha change had no influence on the facets once they had been produced. Moreover, on marking a particular area before heating it could be shown that its structure corresponded with that of the original alpha iron crystal. The boundaries were the same in both cases. On repolishing and etching after heating it bore, however, no relation to the metal underneath, which had recrystallized in passing through  $Ac_3$  and  $Ar_3$ . Furthermore, upon heating the specimen of the iron below 900 degrees Cent. it developed the same characteristic etch facets as at 100 degrees Cent., although the time required was considerably longer (a minimum of two hours). It is clear therefore that the formation of the oxide begins below 900 degrees Cent. and that it takes its shape from the structure of alpha iron, and having once begun it continues to grow, regardless of the phase changes which take place in the iron underneath on passing from alpha to gamma and back again. The authors do not regard the process merely as an oxidation of the iron crystals, by means of which the structure of the iron is made manifest, so much as growth of crystals of an oxide, the orientation of which is determined by the iron on which they are first formed. In certain instances the valleys produced at the boundaries are caused by the growth of oxide crystals away from the true boundary in two directions, the slopes of the valley being made up of the "sides" of the crystals. It will be noticed that these are striated in a regular manner corresponding with the orientation of the facets observed on the surface.

The fact that one substance will assume the same orientation as that of another on which it is crystallizing, provided they are isomorphous, is well known. This was established, for example by Mr. C. V. Baker<sup>1</sup> in his

<sup>1</sup>Journal of the Chemical Society, 1906, vol. lxxxix. p. 1120.



experiments on "the formation of regular growths of crystals of one substance upon those of another." Parallel growth of sodium nitrate crystals on calcite surfaces are shown on Plate XX., Figs. 63, 64, and 65 of Sir George Beilby's book entitled "Aggregation and Flow of Solids." It seems probable, therefore, that in the present case the oxide first formed is magnetite

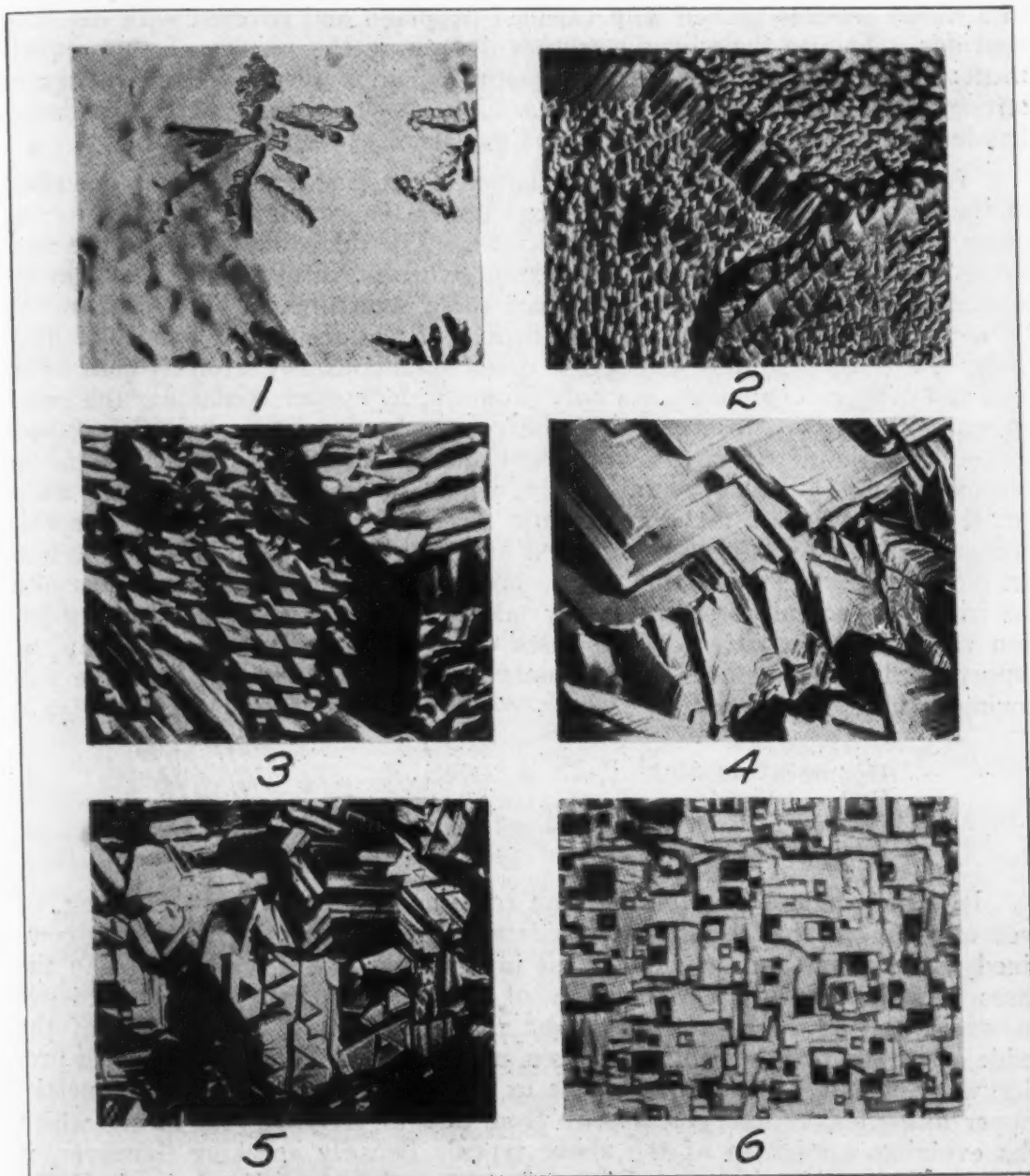


Fig. 1—Copper heated in vacuo in the presence of Armco iron. X 300

Fig. 2—Armco iron heated in vacuo in the presence of copper. X 300

Fig. 3—Armco iron after more prolonged heating. X 600

Fig. 4—Two adjacent grains of electrolytic iron after heating. X 300

Fig. 5—Armco iron after heating in vacuo for two hours, showing rectangular and triangular figures. X 600

Fig. 6—Crystal of electrolytic iron showing minute square and rectangular figures. X 600

$\text{Fe}_3\text{O}_4$ , which has a cubic symmetry like alpha iron. The surface crystals, however, which were removed with a penknife, were not attracted by a magnet, indicating that they had been further oxidized, probably to  $\text{Fe}_2\text{O}_3$ , without

change of form. It is well known that hematite crystallizes in the hexagonal system, but this oxide has been obtained in a form pseudomorphous with magnetite by heating the latter in a blow-pipe flame for several hours. The crystals oxidized without change of form.<sup>2</sup> A type of structure somewhat similar to that described above was obtained by Osmond and Cartaud.<sup>3</sup> They heated to redness a crystal of iron (which had one of the cube faces polished) in a nickel crucible packed with calcined magnesia and covered with cast-iron shavings. To use their own words in describing the results of this experiment: "The polished face oxidized naturally and displayed square figures strongly resembling corrosion figures. . . . It seems that the oxidation has been regulated by the structure of the metal."

As has been already stated, the characteristic structures of oxide described in the present paper are only produced under the combined influence of the gases evolved from both copper and iron. The mere oxidation of the iron which always takes place to some extent when it is heated by itself in an evacuated silica tube, does not produce these structures at all. What has to be explained, if possible, is the oxidation of the iron in a particular way under the combined influence of the gases simultaneously evolved both from iron and copper. The effects are only produced by copper containing the gases normally present in the metal. If the copper be previously heated *in vacuo* several times until no gases are evolved and be then heated with iron in an evacuated tube, it remains quite bright, while the iron oxidizes slightly without the production of the characteristic facets of oxide. Both the composition and volume of the gases contained in copper vary within fairly wide limits. Several samples of the metal, however, produced similar effects on the iron. The action therefore clearly takes place with gases whose composition varies to some extent. The gases collected when one specimen of the copper used in the authors' experiments was melted *in vacuo*, gave the following results on analysis:

	Per Cent.
Hydrogen sulphide .....	61.2
Carbon dioxide .....	34.9
Oxygen .....	1.1
Residual gas (nitrogen) .....	2.8

It is to be noted that this mixture contains only just over 1 per cent. of free oxygen, but that there is a considerable amount of oxygen present combined with carbon and sulphur. Less information exists with regard to the gases present in iron. The majority of gas analyses have been carried out on steels, and in these cases the gases appear to consist of mixtures of the oxide of carbon together with hydrogen and nitrogen. It is impossible to predict what would be the equilibrium in a system composed of the metals, copper and iron, at temperatures of from 900 to 1000 degrees Cent., which was evolving a mixture of the above types. Broadly speaking, however, it appears that under these conditions the atmosphere produced is decidedly oxidizing both as regards the copper and the iron. In their experiments the authors have noticed the deposition of free sulphur in the cooler parts of the quartz tube. This points to the decomposition of the sulphur dioxide always present in the copper, and the result would be the production of free oxygen. Another source of this gas is possibly the decomposition of some

<sup>2</sup> Friedel, *Bull. Soc. Franc. Min.*, 1894, vol. xvii. p. 450.

<sup>3</sup> *Journal of the Iron and Steel Institute*, 1906, No. III. p. 481.

cuprous oxide. The fact that the production of the characteristic facets of oxide requires a period of considerable duration for its completion is due, no doubt, to the gradual liberation of the gases over this period. Those contained in and evolved from the copper must be held to be the chief cause of the characteristic structures of iron oxide produced, but the influence of their possible inter-action with the gases evolved on heating the iron itself must not be lost sight of.

#### SUMMARY

Samples of Armco, electrolytic, and Swedish iron were heated from below 900 to above 1000 degree Cent. in an evacuated quartz tube and oxidized slightly without producing any characteristic crystallographic features on the surface of the metal. If, however, a specimen of copper be introduced as well as containing the gases which are ordinarily present in the metal, a reaction sets in resulting in the gradual production and development of characteristic facets on the surface of the iron. These are due to the production of what is probably the oxide  $\text{Fe}_3\text{O}_4$  which subsequently passes to  $\text{Fe}_2\text{O}_3$  without change of form. The oxide of iron originally produced is isomorphous with alpha iron, and the orientation of the oxide produced on any given crystal is determined by the orientation of the alpha iron itself. It is, in other words, "a parallel growth" of the magnetic iron oxide. Once produced the form of the oxide is uninfluenced by heating the specimen to a temperature at which gamma iron is formed. A somewhat similar phenomenon was observed sixteen years ago by Osmond and Cartaud. The principal agent in the production of the characteristic facets of oxide is the mixture of gases evolved by the copper on heating.

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*QUESTION NO. 32. In choosing a carburizer, what are the essential features that should be considered?*

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*QUESTION NO. 33. What is the role of nickel in steels?*

ANSWER. From a paper by R. R. Abbott. The principal effect of alloying nickel with pure iron is to increase its tensile strength, elastic limit and reduction of area with a decrease in the percentage of elongation. This effect is the same when carbon is present and it has been found that a given amount of nickel produces about the same change in the physical properties irrespective of the carbon content. The normal effect of the addition of nickel up to 8 per cent in an iron-carbon alloy, upon its physical properties is as follows: 0.10 per cent of nickel increases the tensile strength 42 pounds per square inch, the elastic limit 40 pounds per square inch, the reduction of area 0.005 per cent and reduces the elongation 0.01 per cent. Comparing a plain carbon steel of the same analysis but without the nickel content we find that a  $3\frac{1}{2}$  per cent nickel steel will have an increased tensile strength of approximately 14,700 pounds per square inch, an increased elastic limit of approximately 14,000 pounds per square inch, an increased reduction of area of  $1\frac{1}{2}$  per cent with a decreased elongation of  $3\frac{1}{2}$  per cent. We find therefore that the tensile strength and elastic limit are increased by the nickel content probably due to the solid solution which has been formed between the nickel and the iron. In heating a plain carbon steel above the upper critical point, the cementite is dissolved in the iron of the pearlite during the passage through the lower critical point and this solution progressively dissolves the remaining



iron during the heating up to the upper critical point, at which point, it is all dissolved and the solution becomes homogeneous. During cooling a reverse action takes place but when nickel is present, this separation of the cementite from the iron-nickel solution does not progress as completely nor as easily from a plain iron solution and therefore the pearlite areas in the nickel steel are larger and much more poorly defined than in the case of a similar steel without nickel. The effect becomes more marked with rapid cooling and since the pearlite areas are considerably stronger than the iron areas, we find that in practice any nickel steel compared to one without nickel when air cooled will have a greater increase in tensile strength than the figures quoted.

Nickel also lowers the critical points upon heating as well as the magnetic critical point. Increasing the nickel content of the steel the critical temperatures are progressively lowered and it is evident that finally before absorption point will reach atmospheric temperatures and we will then have an austenitic alloy. The higher the carbon content the less nickel it takes to obtain this condition. In quenching a piece of steel rapidly enough from above the upper critical point the result will be the total absence of iron as a constituent of the alloy. The martensite which is thus produced has physical properties quite different from the mechanical mixture present before heating. A martensite containing nickel has a higher tensile strength than elastic limit but a slightly lower reduction are and elongation than in a similar one without the nickel. A heat treated nickel steel while having a somewhat lower reduction of area and elongation than a correspondingly heat treated plain carbon steel it has more than enough increase in strength to compensate for it. In other words, with a given strength nickel steel will have a greater degree of toughness. If we increased the strength of the alloy by means of nickel the loss in reduction of area and percentage of elongation is far below the loss secured when the strength is increased by increasing the carbon content. In other words the nickel as a strengthening element is not accomplished by nearly as much loss in toughness as is carbon. The effect of nickel upon the tensile strength and elastic limit in the heat treated condition varies with the amount of drawing after quenching. Nickel decreases the rate at which steel will absorb carbon in the carburizing process.

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*QUESTION NO. 34. What is meant by the critical range or transformation in a steel?*

*ANSWER.* During the heating of a piece of steel from atmospheric temperature through 1650 degrees Fahr., it undergoes certain changes in structure at definite points. All normal steels experience this change in structure regardless of its carbon content, although the carbon content regulates the number of changes which it undergoes. In order that these changes may be more clearly brought out, for example, we will select a 0.20 per cent carbon steel and refer to Fig. 1 in tracing this change during heating. Assuming that the steel with which we are working is in a normal condition consisting of approximately 25 per cent pearlite and 75 per cent free ferrite we will consider the influence of the critical temperatures or critical range upon the structure of the specimen. As the specimen is slowly heated, very little change in its structure occurs until it reaches the critical point shown as Ac 1. As the heating is continued a complete change in the structure of the pearlite is noted, the pearlite being converted into a new constituent with new characteristics

and is known as austenite. The excess ferrite remains in the unchanged condition. As the heating is continued, the austenite or solid solution of iron and carbon begins to absorb the free ferrite—this condition continues until the upper line *Ac 3* is reached. At this point the remaining free ferrite is absorbed by the austenite so that the structure of the steel above its upper critical point is composed entirely of the solid solution austenite. The zone or range between the lower critical point designated as the line *Ac 1* and the upper line designated as *Ac 3* constitutes the critical range of this particular steel. Combined with these changes in structure there are certain allotropic changes in the ferrite. Ferrite in its normal condition is known as alpha ferrite, being very ductile and having magnetic properties. During the heating above the lower critical point and passing through the critical point shown as line *Ac 2*, the ferrite undergoes a change whereby it becomes practically non-magnetic and is called beta ferrite. As the temperature is increased above the upper critical point designated by line *Ac 3* there is still another change in the allotropic form of the iron which is known as

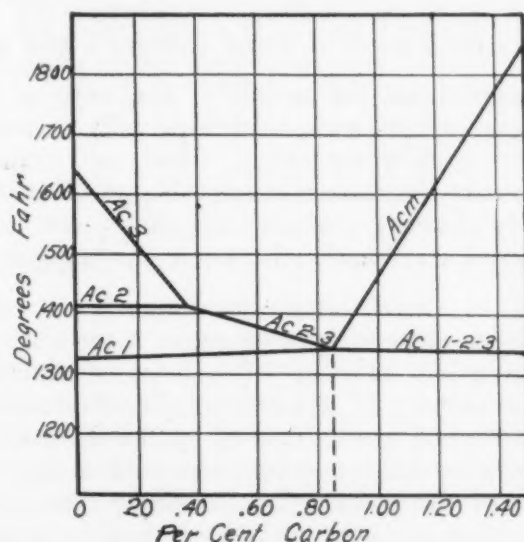


Fig. 1. A portion of the Iron-Carbon Diagram

gamma ferrite. When the ferrite is in the gamma state it has the ability of dissolving carbon or iron carbide.

Steels varying in carbon content, from practically no carbon up to  $1\frac{1}{2}$  per cent, each have their characteristic critical temperature changes upon heating as well as upon cooling. In plotting the points obtained in the examination of steels of various carbon contents, the composite diagram such as shown in Fig. 1 would be the result. However, this diagram is only a partial diagram of the iron-carbon equilibrium diagram. Therefore in considering any steel of specific content its critical range on heating is shown between the lower line *Ac 1* and the upper line *Ac 3* which merges into line *Ac 2-3* at about 0.35 per cent carbon content and at approximately 0.85 per cent carbon content it merges into one line *Ac 1-2-3*. The carbon contents of these steels upon cooling from above the upper critical point *Ac 3* occur in a reverse order and due to the molecular inertia or lag, the critical points in cooling are somewhat below the critical points in heating, however, theoretically, these two criti-

cal points should be identical. The cooling curves are designated as Ar 1, Ar 2, etc.

These characteristics of the alloy, carbon and iron are made use of in the hardening of steels. A close relation exists between the hardening of steel and its critical points, that is in order to harden a piece of steel of a given carbon content, it must be heated through the critical range and quenched. In quenching there is a retention of the structures which give increased hardness and strength which are not possessed by the structures obtained by slow cooling from above the upper critical point.

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*QUESTION NO. 35. What is the difference between red annealed and blue annealed sheet steel?*

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*QUESTION NO. 36. Can mixed lots of steel be identified with a certainty by the aid of the grinding wheel spark test?*

ANSWER. The spark test method of selecting or identifying steel for industrial purposes has been used in many instances and with decided success.

The method is based upon the action of the oxygen of the air, upon the combustible element present in iron, and especially in many of the alloying elements contained in the different steels, which act explosively when heated to a temperature necessary for combustion. To produce bright sparks as the result of heating finely divided particles of metal, the heat must be intense enough to cause chemical combustion between the oxygen of the air and the particles of metal.

If a piece of iron or steel is pressed upon a high speed revolving emery wheel it will throw a great number of sparks, characteristic of the combustible elements in the metal. If it were possible to detect by the quantity or characteristics of the different sparks caused by the different elements that may be in the steel, one might be able to determine with a reasonable degree of accuracy the composition of the metal. The following descriptions of the various types of sparks observed in striking metals of varied compositions on a sharp high speed grinding wheel.

If a piece of wrought iron, free from carbon, is held against a high speed revolving emery wheel, the end of the bar will be heated by friction; as the small heated particles are thrown from the wheel they follow a straight line which becomes broader and more luminous some distance from its source of heat. If the particles are not all consumed they fall to the floor, similar to that of the meteorite or shooting star. The broadening of the streak of light is probably due to the action of the oxygen of the air, requiring some time to act. All commercial iron contains a small percentage of carbon; this will be indicated by a branching or forking of the luminous streak.

In the manufacture of steel, carbon is added to iron; therefore if we touch a piece of mild steel which contains a small percentage of carbon, the effect is at once noted by a division or forking of the luminous streak. This is probably due to the presence of carbon which is acted upon by the maximum heat of the iron spark which burns explosively, causing several breaks in the original heavy line.

With increase of carbon from .50 per cent to .85 per cent the iron spark lines diminish, becoming less conspicuous proportional with increase of car-



bon; the forking of the luminous streak occurring much more frequently, subdividing by re-explosions from the smaller particles. The lower the percentage of carbon the less forking of the heavy lines of light and the farther the sparks will be thrown from their source of heat.

In the highest grades of carbon tool steel the iron lines are practically eliminated with increase of the explosions and subdivisions, causing a beautiful display of figures. This is probably due to the iron and carbon becoming united in such a manner that they are easily attacked by the oxygen of the air. Hence the danger of burning carbon tool steel on the emery wheel and in the fire. It would be well to state here that the higher the percentage of carbon the more profuse the explosions, and the shorter the distance of the sparks from the source of heat.

Practically all high speed steel contains, in addition to carbon, other alloying elements chiefly tungsten and chromium. A noticeable fact is that this class of steel contains about .65 per cent carbon but the particles show no trace of a carbon spark whatever. It is probable that the above elements are so thoroughly combined with the carbon that they prevent its explosion or burning. Hence the metal being much more refractive it will endure high temperature without scaling or burning. Therefore, the temper is not drawn so easily as in carbon steel. It will require considerable pressure on the emery wheel to ignite a spark. Its color is a dark yellow due to the chromium and tungsten. The spark follows a straight line similar to iron except that the broad streak of light is more abrupt, with an occasional branching spark which is probably due to manganese.

The characteristic of a manganese steel spark is that it widely differs from the carbon spark in that it seems to explode at right angles to its lines of force. Each dart is divided and sub-divided into a number of re-explosions which are very distinct. An illustration of this spark can be found in cast iron, high in manganese, while the spark from manganese steel is not so distinct, yet to the trained eye it is easily recognized by its branching appearance. This is probably due to the manganese and other elements becoming so united or combined as to prevent the free explosion of the manganese.

There are many other characteristic sparks, depending upon the amount and combination of the different combustible elements in steel, but to determine the quality by the spark analysis is not at all difficult if we have a known standard sample to compare with the metal under test. In other words, this method of analyzing iron and steel is a comparative test. It is well illustrated if we touch two different grades of material to the wheel at the same time and note the difference in spark characteristic. Cast iron, however, is very difficult to determine by this method, owing to the state and combination of the carbon present. The material being very seldom of standard purity will often show scarcely any luminous sparks at all.

If the carbon is in a combined state the sparks will appear similar to those of steel, proportional to the percentage of carbon so combined.

This method of analysis can be used to advantage to detect if the surface of a piece of steel is or has been decarbonized in its annealing process or otherwise. This condition is quite noticeable in annealed tool steel. It also demonstrates why the quality of steel should not be determined by surface analysis and especially by the spark test. It will also demonstrate how much of the metal must be removed in machine operation in order to reach that

portion containing sufficient carbon suitable for hardening power. This method will also determine the opposite condition, that of carbonizing, commonly known as case-hardening. If the metal has been treated properly the spark will be proportional to the percentage of carbon present and combined with the softer stock. It will also indicate the depth of penetration of the highly carbonized portion, if one cares to destroy the sample at hand.

To give an idea of the advantages of this test, a certain industrial plant desired to have brought together some 8 tons of steel which was very badly mixed up and varied in sizes from very small pieces. The contents of the main tool room inspected and the following list, which was highly interesting resulted:

#### HIGH SPEED STEELS

Bar stock .....	19.5 lbs.
Bethlehem .....	34 "
Blue Chip .....	9.5 "
Columbia .....	144 "
Cutter blades .....	553 "
Jessup .....	8 "
Lathe Tools .....	1728.5 "
Novo .....	93 "
Novo Superior .....	37.5 "
Rex A .....	36.5 "
Rex AA .....	87 "
Red, white and blue, painted.....	217 "
One large boring tool, Salem.....	23.5 "
Short ends .....	299 "
*Scrap .....	380 "
	<hr/>
	3669.5 "

#### AIR HARDENING, CARBON AND OTHER GRADES OF TOOL STEELS

Air hardening tools of different grades of stock .....	2100 lbs.
Carbon bar stock.....	2200 "
Carbon tools lathe, etc.....	1400 "
Carpenter's .....	480 "
Howe .....	310 "
Ketos oil hardening .....	720 "
Midvale .....	300 "
Mushett (old grade) .....	1100 "
Sanderson self-hardening .....	825 "
Scrap carbon .....	2000 "
	<hr/>
	11,435 "
	3,669.5 "
	<hr/>
Grand total amount .....	15,104.5 "

## Abstracts of Technical Articles

Brief Reviews of Publications of Interest  
to Metallurgists and Heat Treaters

By H. E. Gladhill

### CARBONIZING

RECOMMENDED PRACTICE IN CARBONIZING. By S. P. Rockwell. Presented before the Buffalo Meeting of the American Gear Manufacturing association.

Carbonizers should not be judged by speed of penetration alone, but also on the basis of the percentage of carbon in the case and rate of change of carbon as the core is approached. Carbonizers may be classified as follows: (1) Powder materials in which generator and energizer are in powder form, (2) Pellet materials in which generator and energizer are in powder form held together by a binder, (3) Pellet material, the generator being a granular of solid carbonaceous material coated with energizer, (4) Pellet and powder material in which the generator is the pellet and the energizer is in powder form. Each type has its application and should be selected accordingly. The causes of soft spots in the case are discussed. Alloy carbonizing pots are recommended.

SELECTIVE CASE-CARBONIZING. By W. P. Wood and O. W. McMullan. *Chemical and Metallurgical Engineering*, Vol. 26, Page 1077.

Investigations were carried out to obtain if possible a preventative coating in carbonizing work which might be painted on and thus used to advantage where copper plating would not be convenient. From a large number of mixtures tried out, it was found that a mixture of ground asbestos and sodium silicate (not less than 67 per cent sodium silicate) gave good results, preventing carbonization for 24 hours at 1700 degrees Fahr. Aluminum oxide and sodium silicate gave equally good results. The coatings may be removed by dipping the pieces of steel in molten sodium hydroxide or by quenching the pieces in water. The above mixtures were not found as efficient in preventing decarbonization as in preventing carbonizing.

PROTECTION AGAINST CEMENTATION BY DIRECT APPLICATION OF A COATING WITH A BRUSH. By J. Galibourg and M. Ballay, *Revue de Metallurgie*, Vol 19, Page 222.

The use of electrolytically deposited copper as a preventative against cementation is well established. Cost and time considerations prompted investigations of other anti-cementing materials. Copper dust and varnish were found to be ineffectual. Copper dust and sodium silicate were found to work well, but the cost is high



and the material difficult to remove. Copper dust, emery powder, and sodium silicate were found to work well and the cost is considerably lower. Direct immersion of samples into solutions like Heyn's and Stead's reagent were not found to give rugged enough coatings (unless dipped in glue) to be practical.

**HYDROGEN DECARBONIZATION OF CARBON STEELS WITH CONSIDERATIONS ON RELATED PHENOMENA.** By C. R. Austin. Presented at the May Meeting of the (British) Iron and Steel Institute.

The experiments were carried at 680 Cent, 1000 degrees Cent., and at an intermediate temperature. The steels used were 0.40, 0.99 and 1.27 per cent carbon steels. For a given time and temperature the decarbonization was found to increase with decrease in the original carbon content of the steel. After the first 20 hours the decarbonization was found to be very nearly a straight line function of the time. In the case of the high carbon steels, columnar crystals were noted in the ferrite border, and this is attributed to the action of the gas in diffusing outward. Some preliminary experiments on the diffusion of carbon in steel were conducted. Diffusion was found to take place below the A3 point, and from this it is suggested that iron possesses some solubility for carbide of iron. Experiments on decarbonization with a temperature gradient brought out the fact that the total decarbonization was dependent on (a) the rate of removal of carbon by hydrogen, and (b) the rate of diffusion of the carbide.

### INDUSTRIAL RESEARCH

**CO-ORDINATING FOUNDRY CONTROL.** By T. M. Avey, *Iron Trade Review*, Vol. 70, Page 1562.

In a previous article the formation and object of the Electric Steel Founders Research Group were described. The details of co-operation are given in the present article. The director makes periodic visits to each of the plants, and suggests changes and improvements. Operation reports from all departments of each foundry are forwarded to the director at regular intervals, and from this information weak points in operation are pointed out to the various members by the director.

### METALLOGRAPHIC RESEARCH

**THE FORMATION OF GLOBULAR PEARLITE.** By J. H. Whiteley. Presented at the May Meeting of the (British) Iron and Steel Institute.

The investigations of Miers, which have shown the presence of a metastable (crystallization starts by the addition of solid phase) and a labile (crystallization starts spontaneously) region below the regular equilibrium lines in many equilibrium diagrams, offer an explanation of the formation of globular pearlite. Investigations on 0.20 carbon steel bear out the explanation. It is found that with cementite nuclei present, globular pearlite can be formed 15-20 degrees Cent. above lamellar pearlite. The later requires a certain degree of supersaturation. The presence of carbide nuclei also makes possible the accurate determination of

the Ae point. Globular pearlite is found to introduce an earlier growth of lamellar pearlite in adjoining parts of the solid solution. In low carbon steels the tendency to form lamellar pearlite is very strong even in the presence of carbide nuclei.

THE INNER STRUCTURE OF THE PEARLITE GRAIN. By N. I. Bealiew. Presented at the May Meeting of the (British Iron and Steel Institute.

The cementite lamellae are roughly parallel to each other and to the crystallographic plane of the grain. When viewed on a plane at right angles to the crystal plane, the true distance between the lamellae is obtained. When viewed on any other plane, at an angle "w" to the right angle plane, the lamellae appear further apart than they really are. Methods of measuring this angle "w" are given. Some excellent high power photomicrographs of pearlite are shown.

ON THE STEPPED A TRANSFORMATION IN CARBON STEEL DURING A RAPID COOLING. By K. Honda. and T. Hukuta. Presented at the May meeting of the (British) Iron and Steel Institute.

On rapid cooling the Ar 1 point is depressed to about 600 degrees Cent. Still more rapid cooling depresses it discontinuously to 300 degrees Cent. This (300 degrees Cent.) transformation point is considered by some to be of a different nature from the regular Ar 1. Magnetametric and dilatation curves are submitted to show that the points are of the same nature.

ON THE CONSTITUTIONAL DIAGRAM OF THE IRON-CARBON SYSTEM BASED ON RECENT INVESTIGATIONS By K. Honda. Presented at the May Meeting of the (British) Iron and Steel Institute.

Graphitization experiments have shown no justification of the double equilibrium diagram involving graphite. Recent investigations have established the validity of the gamma-delta transformation. The A2 point can be considered only as a magnetic transition, being dependent on temperature alone and not on a time factor. The A<sub>0</sub> or cementite transformation (215 degrees Cent.) must be considered in the category with the A2 point.

X-RAY STUDIES ON THE CRYSTAL STRUCTURE OF STEEL. By A. Westgren and G. Phramen. Presented at the May Meeting of the (British) Iron and Steel Institute.

X-Ray photographs show that alpha beta, and delta (which exists at 1425 degrees Cent.) have the same crystal structure, namely body centered cubic, while the gamma form of iron is face centered cubic. Carbon in solution is shown to have a distorting influence on the crystal lattice of iron. Cementite was subjected to a large number of tests and was found to have a very complex crystal lattice.

INFLUENCE OF GRAPHITE ON IRON. By J. W. Bolton, *Foundry*, Vol. 5, Page 436.

The changes taking place on the solidification and cooling of high carbon-iron alloys are discussed and the conditions under which graphitization takes place are covered. The influence of silicon, sulfur, and manganese on the rate of graphitization are

considered and the constitution of the individual graphite particles is given some attention. No new data is submitted. The article is illustrated with numerous photomicrographs.

### TOOL STEEL

BRAND vs. ANALYSIS IN BUYING TOOL STEEL. By R. H. Davis. Delivered before Convention of the National Association of Purchasing Agents, Rochester, N. Y.

Arguments are presented for and against purchasing tool steel by composition instead of brand. It is argued that buying by composition would simplify purchasing, make uniform heat treatment possible, and cut down duplication in storing. The chief argument against buying on a composition basis is that composition and quality are not comparable properties. It is stated that there are unknown elements which go to make for quality in cutting that as yet there are no tests for.

### METALLURGICAL AND METALLOGRAPHIC PRACTICE

ACCURACY IN TEMPERATURE MEASUREMENTS. By H. C. Knerr. *Forging and Heat Treating*, Vol. 8, Page 235.

A combined error of not more than 1 per cent, of the temperature read, should be tolerated in a thermocouple and measuring instrument used in heat treating steel. The potentiometer is recommended in preference to millivoltmeters for reading the E. M. F. from couples, due to their greater inherent accuracy. Bureau of Standards calibrated noble metal couples should be used for checking the accuracy of base metal couples used in the plant.

PREPARATION OF METAL FOR MICROSCOPIC EXAMINATION. By Wm. Campbell. *Chemical and Metallurgical Engineering*, Vol. 26, Page 1163.

After cutting off the specimen, the surface is roughly prepared by filing or grinding. This is followed by polishing, either mechanical or hand polishing. In this latter case, Commercial 0 and 00 and Hubert 0, 00, and 000 papers are recommended. The final polish is obtained by rouge or alumina. Picric acid (5 per cent solution in alcohol) is recommended for etching wrought iron, steel, and cast iron. Hydrogen peroxide and ammonia is recommended for copper and its alloys. Bearing metals should be etched with dilute nitric acid.

### WELDING

ARC WELDING OF STRUCTURAL STEEL. By E. S. Humphreys. *Iron Age*, Vol. 109, Page 1422.

Welded joints may be produced cheaper commercially than riveted joints. Their dependability remains to be tested. Two sets of tests were run on welds. In the first, various structural shapes were welded and pulled in a testing machine. In the second set, joints of the same longitudinal dimensions but varying thickness were welded and tested. Though the data is limited, the welded joints were found to give very uniform strengths.



ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR  
STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective

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 PADGETT, A. G., (M-7), 5462 Crane Ave., Detroit, Mich.  
 PERRY, D. E., (M-7), 24 Huntington Ave., Shelton, Conn.  
 QUINN, J. M., (M-8), C/o U. S. High Speed Steel & Tool Corp., Green Island, N. Y.  
 RAITHEL, GEO., (M-6), 5602 Greenfield Ave., Milwaukee, Wis.  
 RETZLOFF, O., (M-7), Worthington Pump Corp., Cudahy, Wis.  
 RICH TOOL CO., (S-6), Railway Exchange, Chicago, Ill.  
 SMITH, E. C., (M-7), 1054 Book Bldg., Detroit, Mich.  
 SOCIETE DE MECANIQUE DE GENNERVILLIERS, 12 Rue D'Aguesseau, Paris, France.  
 STEERES, L. J., (M-7), 121 Marys' Ave., Fond du Lak, Wis.  
 TROENDLY, H. P., (M-6), Wm. D. Gibson Co., Clyborn & Willow, Chicago, Ill.  
 VOEDISCH, HUGO, (M-7), Michigan Screw Co., Lansing, Mich.  
 WEBBER, N. B., (A-5), 150 Congress Street, Boston, Mass.  
 WEBBER, R. F., (M-7), 224 "A" St. S. E., Washington, D. C.  
 WILLIAMS, D. R., (A-7), 262 Palace Theater Bldg., Milwaukee, Wis.  
 WILLIAMS, S. D., (M-5), 2409 Penn Street, Harrisburg, Pa.

## MAIL RETURNED

L. ALBUS, JR., 175 Bleacher Street, Brooklyn, N. Y.  
 BOLTON, W. A., Room 526, Y. M. C. A., Syracuse, N. Y.  
 GOFF, NEVILLE, Diamond Chemical Co., 1552 East 26th Street, Cleveland, O.  
 JOHNSON, W. R., 200 Knapp St., Apt. 3, Milwaukee, Wis.  
 LEWIS, M. M., (M-6), 1400 Jones Street, San Francisco, Cal.

NICHOLS, W. H., JR., Box 41 P. E. A., Exeter, N. H.

### CHANGES OF ADDRESS

- BEATTY, I. N., (M-5), from 407 Evans Bldg., Washington, D. C., to 8 S. Frederick Street, Baltimore, Md.
- BOHNER, C. M., from 357 E. Buchtel Ave., to 142 Conger Ave., West Hill, Akron, O.
- BOOTH, C. W., from 68 Batchelder St. to 495 Union Ave., Laconia, N. H.
- BRANIGAN, P., from 447 S. Beech St. to 407 W. Beard Ave., Syracuse, N. Y.
- BROWN, WALTER, from Walter Brown Tool Wks., St. Louis, Mo., to Kent Owens Machine Co., Toledo, Ohio.
- COLTON, H. C., from 216 Pine St. to 247 Central, Springfield, Mass.
- DONELLAN, J. E., from 227 Westminster Ave., Syracuse, N. Y., to Ohio Steel Foundry Co., Lima, O.
- ESSELTINE, A. B., from 2026 N. California Ave. to 5742 S. Richmond St., Chicago, Ill.
- GRIFFEN, R. S., from Carbon Steel Co. to 914 Homewood Ave., Pittsburgh, Pa.
- GRINNELL, A. L., from Garrick Theatre Bldg. to General Motors Bldg., Detroit.
- HARRISON, O. H., from 612 15th St. to 229 London Ave., Rockford, Ill.
- HENTON H. M., from 12301 Buckingham Ave. to 615 Nat'l City Bldg., Cleveland.
- JOSEPH, C. F., from 7420 3rd Ave., Detroit, to 420 W. Ionia St., Lansing, Mich.
- KINGSBURY, J. A., from 2002 S. Miami St. to 527 Leland Ave., South Bend, Ind.
- KUMMER, R., from 469 Elliott Ave. to 2365 W. Clifton Ave., Cincinnati O.
- LINDHOLM, G. F., from 4711 N. Seeley Ave. to 5308 Christiana Ave., Chicago.
- MARBLE, W. H., from 619 State Theatre Bldg. to 6915 Sturgeon St., Ben Avon, Pittsburgh, Pa.
- MATHEWS, F. R., from 14 Princeton St. to 22 Willard Ave., Springfield, Mass.
- MEDWEDEFF, M. M., from 5014 Wesley Ave., Baltimore, Md., to 93 W. Pettibone Forty Fort, Kingston Sta., Pa.
- NISBET, G. B., from 643 W. 8th St., Erie, Pa., to Box 96, Welland, Ont., Can.
- OBERMAIER, J. A., from 430 S. Green St. to 141 Austin Ave., Chicago, Ill.
- REIFSNYDER, CHAS., from 3408 Reach St., Philadelphia, to 934 W. Bridge, Phoenixville Pa.
- SCHMALZ, D. P., from 2842 N. Campbell Ave. to 5939 Grace St., Chicago.
- SELLECK, T. G., from 302 N. Pine Ave. to Room 800, 20 E. Jackson Blvd., Chicago, Ill.
- SIMPSON, C. W., from 13404 Shaw Ave. to 1300 E. 134th St., E. Cleveland, O.
- STIVERS, L. C., JR., from 715½ W. 4th St., Davenport, Ia., to 1st and Grant Sts., Bettendorf, Iowa.
- THOMSON, W. G. H., from P. O. Box 283, Rockford, to 1455 W. 37th St., Chicago, Ill.
- TOWNSEND, A. S., from 1251 E. 124th St. to 1124 E. 125th St., Cleveland, O.
- WALKER, E. C., from 334 N. Grove Ave. to 932 N. Blvd., Oak Park, Ill.
- WICKENDEN, T. H., from Willeys Corp., Elizabeth, N. J., to C/o Zeder Skelton Breer Eng. Co., 24 Mechanics St., Newark, N. J.
- WHITE, R. G., from 239 E. Erie St., Chicago, to C/o W. H. White, 56 Murray St., New York City.
- WHITE, R. J., from 33 Alfred St. to Meredia St., Springfield, Mass.

## News of the Chapters

### SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Friday, Franklin Union, Corner Berkley and Appleton Sts., Meeting 8:00 P. M.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—\*Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Philadelphia—Last Friday, Engineers Club.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering, Bldg., Union College.

South Bend—Second Tuesday in the month.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

### CHICAGO CHAPTER

The First Annual Outing of the Chicago Chapter of the American Society for Steel Treating was held Saturday, June 10, 1922, at the Hartmann House, 23 miles northwest of the "Loop" on the Milwaukee Avenue Road. It was a stag affair. The trip was made in automobiles, transportation being provided for all by those of the members and their friends who had machines.

By 12:45 P. M. all automobiles were on their way. We were fortunate in having a splendid day, the sun shining brightly and there being just enough of a breeze to make the trip enjoyable. The route taken was north on Lake Shore Drive and Sheridan Road to Evanston, west on Dempster Road to Milwaukee Avenue, and north to the Hartmann House.

After exchanging greetings, 207 members and guests sat down to an "Honest to Goodness, old-fashioned home cooked chicken dinner, and all that goes with it; no frills, just food and lots of it." The dinner was excellent and plentiful. We took along our own music and song leader, and during the dinner there was community singing. It did not take the boys long to "warm up," and the talking and laughing that could be heard indicated that everyone was having a good time.

After the dinner, we all retired to the spacious grounds surrounding



the Hartmann House, where group pictures were taken by several of our amateur photographers. Some of the pictures are shown in this issue of the *TRANSACTIONS*. A prize of \$5.00 given for the best photograph was won by Mr. O. T. Hegg, of the Perfection Tool Hardening Company.

An indoor baseball game was started, two teams being chosen among those who desired to play. Pitcher Guthrie was so effective for the victors that he was accused of throwing a "shine ball," with the aid of some Huber's No. 0000 French Polishing Paper.

Many of the boys strolled along the banks of the Desplaines River,



Prize Group Photograph of Chicago Chapter Outing

enjoying the natural scenery, and otherwise occupied themselves. A number of group photographs were taken.

By 5:30 the last of the mighty host were on their way back to Chicago. It was a most enjoyable outing, one to which we will all look back with happy recollections. It was so successful that we may look forward to a bigger and better one next June, when we will again get together without talking of pearlite, hardenite, etc.

Our especial thanks are due the three active members of the Entertainment Committee, namely, Messrs. Havens, Henry and Hardwicke and to the Committee on Membership and the Chairman and Secretary of the chapter. It is to them that all credit goes for the smoothness with which the affair was executed and the large attendance secured.

### A NEW CLUB ORGANIZED

The Ferrite Club of Lewis Institute, Chicago, was organized May twenty-third, nineteen hundred twenty-two, by students interested in discussion of the properties of iron and its alloys. The Club was organized through the efforts of Professor John F. Keller, and has at present thirty members including three of the Institute Faculty. All members of the Ferrite Club also belong to the American Society for Steel Treating.

The object of the club is to discuss articles appearing in various technical publications, and in the *TRANSACTIONS* of the American Society for Steel Treating.

The members of the club have had practical and theoretical instruction in the following subjects: foundry practice, forging, heat treating, metallurgy, and metallography. This knowledge enables the students to discuss intelligently many phases of the subject, "iron and its alloys."

The following officers were elected: Harry A. Devine, President; Harold Kaiser, Vice President; Ernest Wolf, Secretary and Lester Hessler, Treasurer.



Members of Ferrite Club recently organized at Lewis Institute

### NEW YORK CHAPTER

Announcement of the names of chairman for the standing committees for the ensuing year were made and are as follows: Program Committee, Sam Tour; Membership Committee, A. H. Kingsbury; Entertainment Committee, Paul F. McGovern of the General Alloys Company, New York; Research Committee, C. E. McQuigg, General Research Laboratory, Carbide and Carbon Company, Long Island City. The executive committee is made up of the foregoing chairmen; the three officers of the chapter; the retiring chairman, George I. Norris; and three or four others still to be appointed.

The chapter's next meeting will be held the third Wednesday in September and at this meeting brief abstracts of some of the principal papers to be presented at the National Convention in Detroit the week of October 2 will be read and discussed.

### SCHENECTADY CHAPTER

On the 25th of June the Schenectady Chapter held its last meeting in the Civil Engineering Building of Union College. Following the paper of the evening which was presented by Stanley P. Rockwell, Consulting Metallurgist of Hartford, entitled "Carburizing," officers for the ensuing year were elected. They are as follows:

Chairman, B. T. Perry; vice chairman, Richard Topham; secretary-treasurer, G. R. Brophy; executive committee, F. P. McKibben, Mortimer Sayre, H. W. Tymes, W. G. Freer.

The proposed program for the work of the chapter for the ensuing year will be announced later.

### WASHINGTON CHAPTER

The last meeting of the chapter for the season 1921-22 was held on June 30 in the Auditorium of the New Interior Department Building. The program for this meeting was a paper by Prof. H. F. Moore of the University of Illinois, Urbana, Illinois, entitled "Fatigue of Metals." This subject covering the failure of metals by fatigue or the repeated application of stresses, offers a subject of extreme interest to the steel treater, metallurgist, designer and engineer. Prof. Moore has done an extensive amount of work in the investigation of fatigue resisting properties of many steels and delivered a very interesting paper which brought forth a great deal of excellent discussion.

### MILWAUKEE CHAPTER

The Milwaukee Chapter announced the result of their annual election of officers Friday July 21st.

The slate recommended by the Nominating Committee was endorsed by the membership.

The officers for the coming year are as follows: Chairman, A. W. Lorenz; Vice Chairman, H. B. Knowlton; Secretary, H. G. Lloyd. Board of Directors, E. O. Dixon, J. Fletcher Harper, C. B. Langstroth, R. J. Thurner, Hugh Rowan, Chas. Wesley, Jr.

Chairman Lorenz appointed the following committees to assist him in carrying on the work of the chapter for the new year. These committees are as follows: Program Committee, Mr. J. F. Harper, Mr. E. O. Dixon, Mr. H. B. Knowlton. Membership Committee, Mr. C. P. Langstroth, Mr. Chas. Wesley, Jr., Mr. Hugh Rowan. Entertainment Committee, Mr. R. J. Thurner, Mr. H. G. Lloyd.



## Reviews of Recent Patents

**1,408,686. Method and means for carburizing iron, steel, and alloys thereof. Adolph J. B. Bertchy, Omaha, Neb.**

The method of case-carburizing, consisting in heating the treated articles to and maintaining the same at a temperature above the critical temperature for hardening the material; and supply with substantial continuity, so as to maintain about the heated articles a nearly uniform atmosphere thereof, a relatively complex hydrocarbon unstable at the maintained temperature of the articles.

**1,409,119. Annealing furnace. Hugh J. Scanlon, Waynesburg, and Michael B. Kelly, Pittsburgh, Pa., assignors to American Steel Company, Pittsburgh, Pa.**

In an annealing furnace, the combination of a straight-away annealing chamber having an inlet and an outlet, a heating furnace located on one side of the annealing chamber and communicating therewith, said heating furnace being located at some distance from the ends of the annealing chamber, the top of the annealing chamber sloping in opposite directions from a point adjacent the heating furnace, whereby the material on entering the annealing chamber is gradually heated, reaching the maximum temperature at, or about, the heating furnace and being gradually reduced in temperature beyond heating furnace to the outlet.

**1,409,452. Machine for hardening and tempering wire. Charles D. Johnson, Worcester, Mass**

The combination with a machine for the continuous drawing of wire, of a carrier for continuously receiving the wire therefrom, a frame mounted adjacent to the wire-drawing machine, a winding block at the opposite end of the frame for continuously moving the wire along the frame toward the rear, and means mounted along the frame for continuously hardening or tempering the wire delivered from the carrier while on its way to the block.

**1,409,584. Annealing furnace. Charles A. Ross, Detroit, Mich**

The combination with an annealing oven, a bed therein having its end protruding from the oven and providing loading and unloading platforms, an endless conveyor disposed longitudinally of bed, flat and pan like carriers on bed approximately the width of the bed and proportioned relative to the length of the oven and each other so that a carrier is at all times in the oven and another carrier on a platform, bails attached to the carriers and adapted to be connected to the conveyor, and in operating means adapted to impart movement to the conveyor oven.

**1,409,842. Testing machine. Louis E. Foster, Annapolis, Md., assignor to Tinius Olsen Testing Machine Company, Philadelphia, Pa.**

The combination in a testing machine of a frame; a substantially U-shaped yoke slidably mounted thereon; means for reciprocating the yoke, a member also slidably guided in the frame for movement substantially in the line of movement of the yoke; with means on the yoke for gripping the ends of a test specimen and holding it in a line at right angles to the line of movement of the yoke; an other means on the member for operatively engaging the test specimen between its points of engagement by the yoke.

**1,412,152. Hardening and annealing furnace.** Benjamin M. Walpole, Providence R. I., assignor to National Gas Furnace Company, Providence, R. I.

An annealing and hardening furnace comprising a rotary work carrier, a liquid tank, a heat zone above said tank and a skirt extending downwardly into the tank liquid sealing the heat zone against the admission of outer air.

**1,413,134. Liquid-fuel burner.** William R. Purnell, U. S. Navy.

In a liquid fuel burner the combination of means adapted to conduct a fluid atomizing agent under pressure; a helical screw thread on the exterior of the conducting means for dividing the fuel into relatively thin films or streams; means to supply the atomizing agent to the conducting means; means to supply fuel to the screw thread; and a plug having a mixing chamber, a bore connecting the conducting means with the chamber, and a plurality of tangentially disposed passages adapted to conduct fuel delivered from said screw thread to the chamber.

**1,414,180. Heat-treating furnace.** Edgar F. Collins, Schenectady, N. Y., assignor to General Electric Company.

A furnace for heat treating small parts comprising the combination of an enclosure, charge and discharge means substantially sealing the interior of said enclosure from the atmosphere, electric resistors mounted within said enclosure for heating a charge therein, a plurality of containers therein located in discharge and receiving relation to each other, and means for tilting the containers to transfer a charge from one container to another, thereby causing said charge to receive heat uniformly throughout.

**1,414,226. Electric Heating Apparatus.** Wijtse Beije Smits, Dülmen, Netherlands.

An electric heater, comprising a core composed of resistance elements and clamping plates arranged in alternation, and a coating of heat-conducting material enclosing said core, said heat-conducting material having a higher coefficient of expansion than the material of which the clamping plates are constructed.

**1,412,484. Heat treatment of articles of iron and steel and alloys thereof.** William Morris Mordey, Westminster, England.

The heat treatment of an iron or steel article other than a rail, for the purpose of altering and improving the physical condition of the metal of which the article is composed, such treatment consisting in arranging the article in a magnetic field set up between the magnetic poles of a powerful alternate current electro-magnet so that the article will form part of the magnetic circuit of the magnet core and will have induced in it a magnetic flux and consequently eddy currents of such strength as thereby to become heated to the desired temperature limited by the critical non-magnetic temperature of the metal of which the article is composed, and afterwards cooling the said article.

## Commercial Items of Interest

**C**HARLES GRIFFIN & CO., LTD., London, England, announces the publication of a volume by Sir Robert A. Hadfield entitled "The Work and Position of the Metallurgical Chemist" with references to Sheffield and its place in metallurgy. The contents of this book are as follows: Sheffield's Work in the Past and during the War.—The Sheffield Association of Metallurgists and Metallurgical Chemists.—The Chemist.—The Indebtedness of the Metallurgist to Science.—Metallurgical Instruction.—Metallurgy and Poetry.—The Author's Research Work.—Manganese Steel.—Low Hysteresis Steel.—Federation of Engineering Interests.—Electrical Power.—Rapid Cinematography.—American Railroads and their Long Trains.—Ancient Research Workers.—The Royal Society.—Conclusion.

Leeds & Northrup Company have published a booklet on Potentiometer Pyrometers. The booklet points out the functions for which the various types of instruments are intended, and discusses the factors governing the selection of a pyrometer equipment. There are forty-four pages and many illustrations, some of which are in color.

Pittsburgh will be the host of the American Chemical Society at its Annual Fall meeting, from September 4th to September 9th, inclusive. All of the divisional meetings will be held at the Carnegie Institute of Technology, while the general meetings are scheduled at Carnegie Music Hall.

An exceptional program has been outlined for the entire week, with a variety of social events for the Councillors and their wives.

Of outstanding importance in the program will be an address by Thomas Midgley, Jr., of the General Motors Research Corporation on "Chemical Control of Gaseous Detonation with Particular Reference to the Internal Combustion Engine." Mr. Midgley will be assisted by T. A. Boyd. The lecture will include demonstrations of normal combustion and detonation in glass tubes, the suppression of detonation by the addition of certain chemical compounds, and demonstrations with an internal combustion engine motor containing quartz windows and apparatus for measuring radiation. The motor will be operated on detonating and non-detonating fuels. Lantern slides will be shown illustrating the periodic variation of anti-knock value among the 16 elements. Blue-prints of the paper will be issued at the meeting.

"Pittsburgh as a Chemical Manufacturing Center" is the subject of an address to be given by Dr. J. H. James, Head of the Department of Chemical Engineering, and Dr. W. F. Rittman, Head of the Department of Commercial Engineering, of Carnegie Institute of Technology. Dr. James will discuss "Pittsburgh's Raw Materials and Markets for Chemical Products." Dr. Rittman will speak on "Pittsburgh's Transportation and Financial Advantages."

By special arrangements, the Committee of the Pittsburgh Section of the A. C. S. has obtained dormitory privileges for the Councillors at Carnegie Tech during the Meeting. The Men's Dormitories will be opened to house 350. One of the Women's Dormitories has been offered for the use of Councillor's wives.



## EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

### Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

### POSITION WANTED

**METALLURGIST or SUPT. HEAT TREATING**—Technical graduate. University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

**METALLURGIST**—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

**SUPERVISOR HEAT TREATING.** Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U. S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired \$200.00 per month. Answer 3-25.

**ENGINEERING or PRODUCTION WORK**—Technical Graduate. 2 years heat treatment of armor plate, guns, etc. 2 years charge heat treatment auto parts. 2 years charge commercial heat treating shop. At present employed as equipment sales agent. Desire to make change to engineering or production work. Salary desired \$200-\$250. per month. Address 5-25.

**SALESMAN**—Graduate University of Pittsburgh. 3 years chemist. 3½ years chemist and metallurgist. 3½ metallurgist and chief inspector. Experience in all departments of mill work, rods, wire, plates, spikes, etc. Familiar with nearly all classes of steels including alloys. Location preferred Pittsburgh. Address 5-30.

**METALLURGIST**—10 years experience in carburizing and heat treatment of carbon, alloy and tool steels. Extensive experience in physical testing, metallography, pyrometry and metallurgical research. Also experienced in handling large forces of men. Have had as many as 600 men under my supervision. Eastern location preferred. Salary desired \$4500. per year. Address 5-35.

**SUPERVISOR HEAT TREATING**—Or assistant. Ten years experience as chemist on iron and steel. One year practical experience on metallurgical inspection directly connected with heat treatment. Have made a study of the subject. No preference as to location. Wages \$40.00 per week desired. Answer 5-50.

**FURNACE DESIGNER and BUILDER**—Steel treating furnaces or to take charge of furnace construction and repairs in steel treating department of large manufacturing plant. A number of years experience designing, building and operating furnaces of all types for all classes of work including mechanical and automatic furnaces for heat-treating, carbonizing, and annealing. Willing to make part of compensation dependent upon ability to improve quality of work and reduce costs. Location immaterial. Address 5-5.

**ASSISTANT METALLURGIST**—4½ years experience in U. S. Armories, 4 years laboratories brass rolling mill and shell factory. Experience included installation and maintenance pyrometers, research work, micro examinations and microphotography, critical temperature measurements and carburizing and heat treatment of small parts. Willing to consider any position in metallurgical department, annealing or heat treating department providing there is opportunity for advancement. Wages desired \$150.00 per month. Location preferred Rhode Island, Massachusetts, or Connecticut. Address 5-15.

**METALLURGIST AND ENGINEER**—Experience in purchasing, production, layout, forge shop, heat treating, laboratory and research work. Capable of taking entire charge of malleable, gray iron, semi steel or steel foundry. Desires employment with progressive firm. Address 5-41.

**CHEMIST**—Metallurgist, metallographist, physical tester or heat treater. 12 years experience. Former Government metallurgist. Now an executive with large motor truck company. Also malleable and semi-steel foundry experience. Can organize and manage men. No location preferred. Address 5-10.

**METALLOGRAPHIST** desires position in charge of or as assistant in metallographical laboratory. Has had four years experience U. S. Bureau of Standards. Address 8-10

**WANTED** by a practical man with 22 years' experience with some leading firms of the United States, position as Supervisor or foreman of Heat Treating. Address 8-5

Was connected with United States Naval Ordnance Plant having charge of metallography and heat treatment the past two years, has had practical electric melting experience. Best of recommendations. No restrictions of location. Address 4-35.

**HEAT TREATING DEPARTMENT**—Technical graduate. Hardening room automobile firm. Experienced on aluminum castings. Die Superintendent and metallurgist for steel tool company. Salary \$150.00. Cleveland location preferred. Address 4-10.

## EMPLOYMENT SERVICE BUREAU

### POSITION WANTED

**SUPERINTENDENT OF HEAT TREATING**—7 years experience heat treating of carbon, highspeed and other alloy steels. Experience in metallographic testing. Understands pyrometry. Technical education. Best of references. Location desired, Chicago or near vicinity. Address 6-15.

**SERVICE MAN**—for steel company. Experience in heat treatment of carbon, high speed and alloy steels, also metallographic testing and pyrometry. Technical education. Best references. Address 6-20.

**SALES REPRESENTATIVE**—At present holding responsible executive position. Desires to become representative of one or more manufacturing lines in excellent territory. Companies especially desiring representative for materials used in heat treating will find it to their advantage to correspond with No. 7-5.

**CHEMIST AND METALLURGIST**—thoroughly experienced in analysis of ferrous and nonferrous metals. Specialist in alloy steel analysis. Capable of taking charge of chemical and physical laboratory. Best of references. Age 30. Married. Salary commensurate with ability. Answer 7-20.

**CHEMICAL AND METALLURGICAL ENGINEER** with business education and 3 years practical consulting experience desires a position in laboratory or production departments. Address 7-30.

### POSITIONS OPEN

**WANTED**—Practical Superintendent for tool steel wire and shape drawing department. Reply box 6-5. care American Society for Steel Treating.

**WANTED**—In tool and alloy steel research department 1921-1922 technical graduate who has specialized in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-15.

### WANTED

**WANTED**—A copy of the book "LIGHT WAVES AND THEIR USES" by A. A. Michelson. State price. Address 8-1

### FOR SALE

**FOR SALE**—Commercial Heat Treating Plant. Established business in good field. Excellent opportunity for young metallurgist to get into business for himself. Answer 7-10.

Leeds & Northrup, Hump Method, Electric Furnace for sale. Used very little. Address 6-1.

**FOR SALE**—A ten-ton Gronwell-Dixon electric furnace with all accessories. This furnace is in excellent condition and is available at a very attractive figure. Address 7-25.

*(Continued from Page 1067)*

The daily service that is being rendered by one of the important branches of the iron and steel business is outlined in a pamphlet entitled "Certified Malleable in Transportation and Industry," issued by the American Malleable Castings Association, Cleveland. It tells the story of certified malleable castings, outlining the means employed by the association in bringing the product of its members to a uniformly high standard and maintaining it at that point. It will be sent to interested persons upon written request to the American Malleable Castings Association, 1900 Euclid Building, Cleveland.

The American Electrochemical Society announces the removal of its national headquarters to Columbia University, New York, after having been located for nearly 20 years at Lehigh University, Bethlehem, Pa. This change is due to the fact that the society's new secretary, Dr. Colin G. Fink, who succeeded the late Dr. Joseph W. Richards, has recently been appointed lecturer in electrochemistry at Columbia, and he will have charge of that division of the university's department of chemical engineering.

By recent action of the society, the adoption of an amendment to the constitution raises the annual dues from \$5 to \$8. By action of the directors, the organization of a division of organic electrochemistry has been authorized with A W. Burwell as temporary chairman.

G. M. Sherman, formerly representing the Quigley Furnace Specialties Company, has become connected with the Keystone Refractories Company of New York and has been made New England Sales Manager with offices at 818 Hospital Trust Building, Providence, R. I.

Charles H. McKnight, who has held the positions of president and chairman of the Carbon Steel Co., Pittsburgh, resigned from the former office at a

recent meeting of the board of directors. His successor is C. F. Blue, Jr., who has been vice-president and Frank C. Neale, president of Kitanning Iron & Steel Mfg. Co., controlled by the Carbon Steel Co., and a director of the latter, has been made vice-president, in succession to Mr. Blue.

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Tate-Jones & Co., Inc., Pittsburgh, furnace engineers, within the past few weeks have closed contracts for 13 Costello patent continuous pair furnaces. Six of these were for the Wheeling Steel Corp., Wheeling, W. Va., six for the Newton Steel Co., Newton Falls, O.; and one for the Superior Sheet Steel Co., Canton, O.

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Carnegie Institute of Technology at Pittsburgh has been selected by the United States Naval Academy at Annapolis to give advanced courses in Metallurgy to its graduate officers. The institution is the only school in the country chosen for this work, and its selection is an outstanding tribute to the high standard of its engineering curricula.

Beginning next September, the Naval Academy will send two ordnance officers, graduates of the Academy, for a year's study in advanced metallurgy, at Tech. The officers will be here for the full college year. Their studies will be graduate work in advanced metallurgy with some studies in electricity and physical chemistry. Other groups of graduate officers are assigned each year to various colleges or universities to study along specialized lines.

F. F. McIntosh, Associate Professor in Metallurgy, at Carnegie Tech, will supervise the studies of the Naval Officers. Lieutenants Gilbert C. Hoover and John H. Keefe have been assigned to take the work the next college year.

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P. J. Connor, formerly traveling representative for the International Machine Tool Co., Indianapolis, manufacturer of the Libby turret lathe and who recently resigned from the Essley Machinery Co., Chicago, is now engaged with the Haynes Stellite Co., Chicago, in an engineering capacity with headquarters at New York.

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The Brown Instrument Co., Philadelphia, has published a catalog in which resistance thermometers are described and illustrated. These operate upon the basis of electrical resistance rather than pressure and they are accurate and rapid. It is claimed that for installation where extreme accuracy is required within a small range of temperature, these thermometers are ideal.

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A month's test was recently conducted to determine the utility of a Bailly 1-ton nose-tilting type furnace in one of the oldest brass-rolling mills in England. The test charges consisted of cartridge shells and rolling mill scrap, pouring 60-40 brass into round billets, strip molds and condenser plates.

In the test on round billets, 3 to 6 inches in diameter, operating the furnace continuously for 31 heats, 50 hours was consumed in melting and a total of 48,608 pounds of brass was poured. The electrical energy consumed was 306 kilowatt-hours per ton of metal melted.

With a similar charge of cartridge shells and rolling mill scrap pouring 60-40 brass into condenser plates weighing 1700 pounds each 18 heats required

*(Continued on Page 36)*



# SIMONDS STEEL

CRUCIBLE ——— ELECTRIC

High Speed Steel

Magnet Steels

Chrome Ball and Bearing Steels

Carbon and Alloy Tool Steels

Special Steels

TO know that the steel ordered today will duplicate in every respect that which gave unusual efficiency six months ago, is a satisfaction to the consumer made possible only by years of experience in making **QUALITY Steels UNIFORM** at all times.

**S**IMONDS STEEL in your hardening room allows you fixed temperatures in heat treating and eliminates those costly "trouble days".

We Develop Steels Required  
For Particular Hard Usage

**Bars**

**Sheets**

**Billets**

**SIMONDS MANUFACTURING CO.  
STEEL MILLS**

**LOCKPORT, N. Y.**

Edgar T. Ward Sons Co., Distributors

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(Continued from Page 1070)

31 hours and 49 minutes. The total metal melted was 30,744 pounds at an energy consumption of 276 kilowatt-hours per ton of metal melted.

At a recent meeting of the German Metallographical society J. Czochralski read a paper on counter-crystallization resulting from strain. He defined this expression as recrystallization resulting from a previous mechanical strain of the metals and expressly excepted crystallization arising from molten metal and in phase transformation in solid metals. He regards as erroneous the view that a grain growth appears in metals solidified from a liquid state and cited experiments to show that even with the purest experimental metals, such as gold, it is impossible to observe any detrimental growth of casting crystals.

After giving a historical survey of the subject, Mr. Czochralski described the present position of the counter-crystallization theory, and said that the influence of time now appeared to be the one uncertain factor remaining. The counter-crystallization phases hitherto obtained, all apply, he said, to a definite duration of the temperature influence. Oberhoffer's work seems to show that with a particular degree of strain being exceeded, the grain increase curves do not ultimately lie asymptotically but tend towards high grain-size values in accordance with an unknown law. It is possible that with a sufficiently long period the same grain sizes might be obtained with one and the same temperature of fusion notwithstanding differences in the degree of strain.

Tate-Jones & Co., Inc., Pittsburgh, is circulating a 4-page illustrated folder in which general hardening furnaces are described and illustrated. These are of the semi-muffle type, either for oil or gas fuel. These furnaces are designed to harden and anneal both high speed and carbon steels. The furnaces are fired by one burner. Sight hole and suitable pyrometer openings are provided. All that is required for operation, according to the booklet, is a small amount of compressed air at from 15 to 100 pounds pressure. This is piped to the furnace by a rubber hose attached to the upper compartment of the tank. There the air pressure is reduced, part of the air going to the burner for atomization and part to the lower compartment for pressure upon oil.

The American Malleable Castings association, Cleveland, is circulating a 32-page illustrated booklet entitled "Certified Malleable in Transportation and Industry." The booklet contains an interesting story of malleable castings, made according to the exacting requirements of the American Malleable Castings association and their contribution to safety, strength, and economy in all branches of transportation and industry. The booklet not only points out the great responsibility that malleable castings assume when used for vital parts of automotive, railway, farm implements and general industrial construction, but also outlines the means employed by the association in bringing the product of its members to a uniformly high standard. The booklet is a complete treatise on malleable iron.

It appears from the series of tests which the Bureau of Standards has carried out upon the corrosion of chromium steel, that the behavior of the

(Continued on Page 38)



## Temperature

With the **F. and F. Optical Pyrometer** the temperature is measured by merely observing the object. It is accurate, simple and substantial.

*(Write for Booklet)*

## Hardness

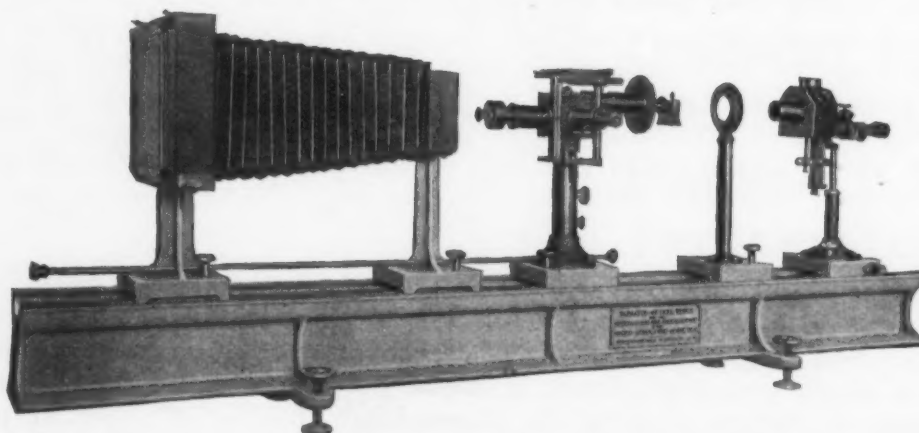
The **S. M. Co. Brinell Machine** is the standard machine for measuring hardness of metals adopted by more than 100 leading concerns.

Pressure is applied quickly and uniformly; a special feature prevents leakage of the hydraulic fluid.

*(Ask for Booklet on Hardness Tests)*



## Micro-Structure



The **Scimatco Optical Bench** is the advanced outfit used by many of the foremost metallurgical firms for observing and photographing the micro structure of metals.

**SCIENTIFIC MATERIALS COMPANY**

*"Everything for the Laboratory"*

PITTSBURGH, PA.

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(Continued from Page 36)

material when subjected to the acid test is not a sure criterion of its resistance to atmospheric corrosion. Of all the alloys examined, a high nickel-chromium steel, invar, pure iron, and medium carbon steel (very slowly cooled from a high temperature) were the most resistant to hydrochloric acid as measured by the loss of weight per unit area per day. High chromium steels (for example, 13.70 per cent chromium, 0.29 per cent carbon) were found to be attacked by acid very much more readily.

However, when the same specimens were subjected to a weathering test, consisting of a partial immersion in water and exposure to the air, the order of resistance was almost completely reversed. The high chromium steels were the ones to withstand the treatment best, the low chromium ones and the pure iron showing rust spots early in the test. The combination of both nickel and chromium appear to make the steel resistant to both acid and weather attack.

In general, the steels which were quenched were found to resist corrosion better than the same material in the annealed state, but the differences found were much less than the differences resulting from composition changes, thus indicating that composition rather than treatment should receive primary consideration.

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The first progress report to members of the advisory board to the Bureau of Mines and the Bureau of Standards on the breakage and heat treatment of rock drill steels and other steels and alloys subjected to similar impact stresses has been made by Dr. H. Foster Bain, director Bureau of Mines, and Dr. S. W. Stratton, director Bureau of Standards, covering the work done in the month of April.

The survey was begun on April 1 with the object of determining the present status of the types and sizes of drills as related to the heat treatment and breakage of rock drill steels. During that month a large number of mines, largely copper, were visited by F. B. Foley, and H. S. Burnholz, metallurgists Bureau of Standards. The report, which is a lengthy one, gives the practice of each mine as to the kind of bit, the size of steel and in some cases the heat treatment used. No conclusions are drawn or comments made.

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In Scientific Paper of the Bureau of Standards, No. 433, entitled, "Thermal Expansion of a Few Steels," the critical regions of steel are used as a basis for heat treatment in securing or retaining desirable qualities such as hardness, elastic properties, tensile strength, etc. Data are presented in tabular form and in curves showing the dimensional changes of steel in passing through these regions. Electrolytic iron and cast iron are also included. One specimen of hardened steel is analyzed, by dimensional changes, to show the release of strains on heating.

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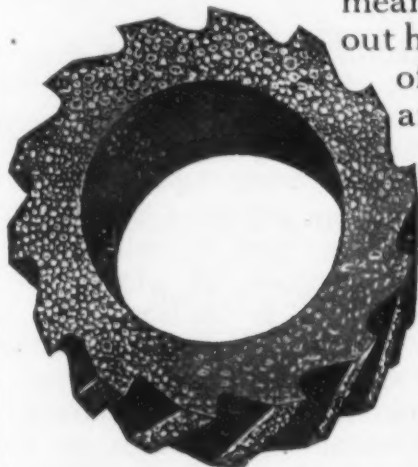
Sir Robert A. Hadfield has presented to the Metallografiska Institutet, Stockholm, Sweden, a scholarship of £150 per year for two years. This is to be made available to a young scientist for carrying on special research work at the institute, and has been given as "an expression of the debt of

(Continued on Page 40)

# SKAILNOT

Scale Preventative  
(Open Hearth Process)

Has no action on the steel other than shutting out the surface-destroying furnace gases, thus providing a simple means of turning out hardened tools of good appearance, with sharp cutting edges, and free from surface defects.



UNPROTECTED

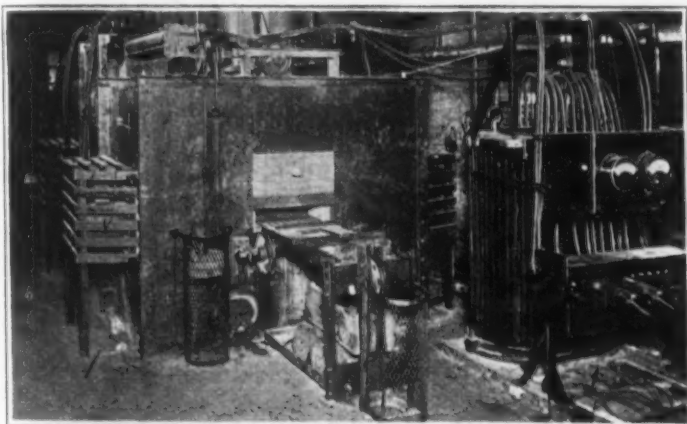


PROTECTED

SKAILNOT does not case-harden

In half-gln. (7 lbs.)  
and gln. (14 lbs.) cans.

**COATS MACHINE TOOL COMPANY, Inc.**  
110 West 40th St., New York



Electric Steel Treating Furnace insulated throughout with SIL-O-CEL

## To Secure Uniform Heat and Positive Temperatures

apply to your furnaces  
a layer of SIL-O-CEL  
Insulation.

SIL-O-CEL is light in weight, highly siliceous, and possesses the lowest heat conductivity of any known material. It withstands extremely high temperatures, acting as a barrier to heat flow through walls and settings, and making it possible to regulate heat with absolute accuracy. Furnished in the form of brick, block, powder and cement, adapted to all types of equipment without change in design.

Complete information contained in Bulletin F-8B sent with blueprints and samples upon request.

### CELITE PRODUCTS COMPANY

NEW YORK - 11 BROADWAY DETROIT - BOCK BUILDING DENVER - SYMES BUILDING  
PHILADELPHIA - BULLETTIN BLDG. CHICAGO - HORNADOCK BLDG. LOS ANGELES - WATTS BLDG.  
CLEVELAND - BULLLEY BLDG. ST. LOUIS - BARNETT EXCHANGE BLDG. SAN FRANCISCO - HORNADOCK BLDG.  
MINNEAPOLIS - 231 SIXTH AVENUE, SOUTH NEW ORLEANS - WHITNEY CENTRAL BANK BUILDING

# SIL-O-CEL

PREVENTS HEAT PENETRATION

TRADE MARK REGISTERED U.S. PATENT OFFICE

A CELITE PRODUCT

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(Continued from Page 38)

gratitude which the world owes to Swedish science." He called particular attention to the contributions of the early Swedish workers in the practical metallurgy of iron.

At the inauguration of the institute, Dr. Carl Benedicks, the director, referred to the lead in modern metallurgy which England had taken, mentioning particularly Henry Clifton Sorby and Sir Robert A. Hadfield, both of Sheffield. He paid touching tribute to the recent great loss which the metallurgical world had sustained in the death of Prof. Henry M. Howe, of New York.

It was the pioneer work of the early Swedish scientists, more than a century ago, which gave the world the first alloy steels. And Bergman, the founder of analytical chemistry, showed the influence of carbon on iron and first defined and differentiated pig iron, wrought iron and steel.

The National Safety Council, 168 North Michigan avenue, Chicago, will hold its eleventh annual meeting in Detroit Aug. 28 to Sept. 1, inclusive. A special program has been arranged for the metals section, of which J. R. Mulligan, safety inspector of the Bethlehem Steel Co., is chairman. J. A. Northwood, safety engineer, Cambria Steel Co., is vice-chairman, and Walter Hart, safety inspector, Jones & Laughlin Steel Co., is secretary. The program will include reports of officers and committees and several addresses, among which these have been announced: "Outstanding Features of the Safety Movement in Iron and Steel, 1910-1919," by Dr. L. W. Chaney, United States Bureau of Labor Statistics, Washington; "Safety in Electric Furnace Operation," by E. T. Moore, electrical engineer, Halcomb Steel Co., Syracuse, N. Y.; "The Safe Handling of Gas at the Blast Furnace" and "Safety in Crane Repairing," for which no speakers have yet been announced.

There will be a joint meeting of the automotive, drop forge and metals sections on Friday, Sept. 1, at 9 a. m.

All meetings will be held in the new Cass Technical High School, which has just been completed. This building has an auditorium with a seating capacity for 3000 persons. Other rooms are available in the same building for sectional and committee meetings.

The Colonial Steel Co., of Pittsburgh, announces the opening of their new warehouse at 2121 St. Clair avenue, Cleveland, O. The stock which is being carried is the complete line of Colonial High Speed and Carbon Tool Steels. F. L. Stevenson, is manager for the district.

The American Rolling Mills Company at Middletown, Ohio, has been reported to have suffered a severe loss through a fire caused by an electrical storm in which the electrical power house of their plant was destroyed.

Charles Engelhard, Inc., have recently issued a new Bulletin No. 24 which describes in detail their automatic temperature regulator. This bulletin may be had upon request to Charles Engelhard, Inc., 30 Church street, New York City.

The Modern Equipment Company of Taunton, Mass., have announced that in the future they will operate under the name of Eaton Electric Furnace Company, specializing in the manufacture of electric, gas and oil ovens and

(Continued on Page 42)



# COLONIAL TOOL STEELS

*Another job done well  
with COLONIAL*

**T**HREE hundred per cent is a big jump in the production of a die, but that was the record accomplished in the plant of T. E. Bennett Co. using Colonial Special No. 14 Tool Steel.

For every Tool Steel requirement there is a Colonial brand that will give you satisfactory service. Colonial Uniformity is the best assurance of greater production at less cost.

ESTABLISHED 1894  
**T. E. BENNETT CO.**  
*Makers of*  
**JEWELRY  
AND NOVELTIES**  
7 BEVERLY STREET  
PROVIDENCE, R. I.

Dec. 7, 1921

Colonial Steel Co.,  
Boston, Mass.

Dear Sirs:—

In response to your letter of the 30th relative to the report given your Mr. Muller on the result of the work done on a blanking die made of your Colonial Special No. 14, we confirm same as follows:—

The best steel we could formerly get gave us 10 barrels of stampings.

Colonial Special did the following:—

On first hardening we obtained 30 barrels of stampings, per sample.

Then the die was annealed, redressed and re-hardened and put to work a second time, at which we obtained 18 barrels of stampings. - A total of 48 barrels.

Shrinkage was hardly noticeable.

Yours very truly,

T. E. Bennett Co.

(Signed) E. L. Bennett, Sec'y

## Colonial Steel Company

Pittsburgh

Boston

New Haven

New York

Cleveland

Detroit

Chicago

St. Louis

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(Continued from Page 40)

furnaces for the heat treatment of steel and other metals. This change in name was due to the fact that the original name did not properly indicate the nature of their product.

A national meeting of the Society of Automotive Engineers will be held in Detroit, October 26-27 for the purpose of discussing problems of automotive production. The meeting is to be known as the S. A. E. Automotive Production Meeting.

Papers treating current production problems in a simple and practical way will be read and fully discussed in morning meetings on each of the two days. The afternoons will be devoted to factory inspection trips especially arranged for the purpose of viewing new and advanced production methods that will particularly interest the tool, inspection and production men. The principal object of this meeting is the promotion of an interchange of experience between practical factory men on automotive production problems which are troubling them in their daily work.

An S. A. E. Production Dinner will be held Thursday evening, October 26, where social friendships between production men will be promoted. Announcement of the locations of the meetings and dinner will be made in the near future.

Special Committees of Detroit S. A. E. members are in charge of the arrangements for this national meeting. K. L. Herrman, a Studebaker production engineer, is Chairman of the Committee which is selecting the papers and topics for discussion. Suggestions or requests to present papers should be addressed to the S. A. E. New York office. Papers must be submitted before August 15.

Buell, Scheib, Mueller, Incorporated, consulting and combustion engineers have announced the opening of their office June 1, 1922, in the Columbian Bank Building, Pittsburgh. Messrs. Buel, Scheib and Mueller are specializing in fuel economy and conservation as well as furnace design.

Hoskins Manufacturing Company of Detroit wishes to announce that the territory formerly handled from the Pittsburgh office is now being handled by their Cleveland office. The address of their Cleveland office has been changed from 410 Sloan Building to 947 Leader-News Building. J. D. Sterling is District Manager.

## Show Your Colors



ALL MEMBERS of the A. S. S. T. should make a practice of wearing the Society emblem. It is neat and inconspicuous and immediately conveys the information that the wearer is a progressive individual and a member of a live, wide awake organization. The pin is in black and gold as shown above, with safety fastener, and will be mailed, post paid upon receipt of \$1.00.

**AMERICAN SOCIETY FOR STEEL TREATING**

4600 Prospect Ave.

Cleveland, Ohio

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Auto-

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